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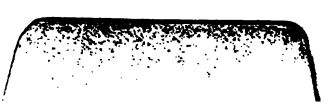

Talking Machines and Records.

TALKING MACHINES & RECORDS.

A HANDBOOK FOR ALL WHO USE THEM.

ILLUSTRATED WITH EXAMPLES OF DIFFERENT TYPES OF INSTRUMENTS, WITH FULL INSTRUCTIONS FOR MAKING A SIMPLE PHONOGRAPH, AND THE PRODUCTION OF "BLANKS" AND RECORDS.

By S. R. BOTTONE,

AUTHOR OF "AMATEUR ELECTRICIAN'S WORKSHOP," "IGNITION DEVICES," "ELECTRICAL ENGINEERING FOR STUDENTS," ETC., ETC.

WITH 40 ILLUSTRATIONS.

LONDON:
GUILBERT PITMAN,
86 & 87, FLEET STREET, E.C.

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PREFACE.

THE Phonograph and Gramophone are now so well known as not to call for any detailed description of their appearance; but as many are not so conversant with the mode in which they act, either with regard to their power of recording or that of afterwards reproducing sound, we give in the following pages sufficient information to enable anyone to form an intelligent conception of the acoustic principles which govern the phenomena, and which enable the talking machine to make a memorandum or "record" of any sound, be it noise or music, speech or howl, emitted within its range—and then from this record to reproduce, at the will of the operator, the sounds thereon originally impressed. We follow this up by a brief historical outline of the work of different experimenters, which has culminated in the Phonograph as we now know it, with its perfected mechanical devices. We also give directions for making a simple but efficient form, giving due prominence to the different types of recorders, records, and reproducers, as well as to the more delicate and noiseless forms of mechanism adapted to imparting the necessary motion to the records.

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LIST OF ILLUSTRATIONS.

FIG.		PAGE.
1.	Rendering Sound Vibrations Visible...	10
2.	Léon Scott's Phonautograph	12
3.	Tracings Produced by Sound	14
4.	Kratzenstein's Reeds	15
5.	Kempelen's Talking Machine	16
5A.	Kempelen's Improved Machine	17
6.	Edison's First Phonograph	21
7.	Edison's; Bidwell's Modification	23
8.	Bidwell's Sectional View	25
9.	Bidwell's Speaking Point	26
10.	Electro-Motor for Phonographs	32
11.	Barrel Spring Motor	36
12.	Open Spring Motor	37
13.	Gearing of Motor	39
14.	Three-Ball Governor	40
15.	Guide-Bar Arrangement...	42
16.	Recorder, Section and Elevation	48
17.	Recorder in Perspective	48
18.	Box of Reproducer	51
19.	Tube of Reproducer	51
20.	Elevation of Reproducer	52
21.	Section of Reproducer	52
22.	Drawing Glass Threads...	54
23.	Making Glass Bead	55
24.	Magnified Glass Bead	55

LIST OF ILLUSTRATIONS—*Contd.*

FIG.		PAGE.
25.	Star Support for Bead	56
26.	*a* and *b*, Bettini Reproducer	57
26.	*c*, *d*, and *e*, Various Reproducers	58
27.	Horn, Suspended	59
28.	Balanced Reproducer	61
29.	Pattern for Horn	63
30.	Coning Horn	63
31.	Making Records	67
32.	Blanks	70
33.	Gold Coating	71
34.	Record Cast	70
35.	Moulding in Wax	74
36.	Pantographic Duplicator	77
37.	Attachment of Balanced Reproducer...	79
38.	Phonograph and Gramophone Tracks	81
39.	Gramophone Sound-box	82
40.	Gramophone Complete	84

Talking Machines.

§ 1. All sounds recognisable by the ear are due to wave-like motions in the sonorous body or in the air. The slower the waves, the lower or gruffer the sound produced. Shrill sounds are due to very rapid wavelets. Our ears are so constituted that ordinary healthy individuals can recognise sounds produced by vibrations lying between 16 and 40,000 per second. There is a little difference between the delicacy of hearing which some people have with regard to the extreme high and extreme low rates of vibrations. Some can hear the squeak of a bat (which is the result of about 44,000 per second) at a time when others maintain that there is no sound at all. In like manner those who hear the squeak of a bat or the chirping of the katydid (an American kind of grasshopper) are often incapable of taking any cognizance of the low roar or boom produced by the slower vibrations. Although nearly all elastic bodies are capable of transmitting the waves, upon which sound depends, to the ear, yet we usually receive our impressions through the air. There are several ways in which we can render evident to the eye the motion giving rise to sound. As we are convinced that no knowledge is so easily acquired

or so fully retained as that gained from experiments, we strongly recommend the reader to perform the following, which will show at once the existence of the wave-motion and its propagation in all directions. Let a very thin champagne glass be procured and mounted in the centre of a board, from which arises a wooden rod or wire standard about twice the height of the glass (see Fig. 1). From this rod, at right angles to it, projects a wooden or wire arm, reaching to about the centre of the glass. This bears upon its upper surface a four or six-rayed wire star, suspended from the extremities of which by fine threads are an equal number of small balls, which may be either of pith, of ivory, or of imitation coral. These balls must just touch the rim of the glass at equidistant points round its circumference. If now the experimenter rub the bow of a violin with resin, and then draw it steadily along the edge of the glass, he will set it vibrating, and consequently cause it to give out a musical note. The vibrations of the glass will not be visible, so

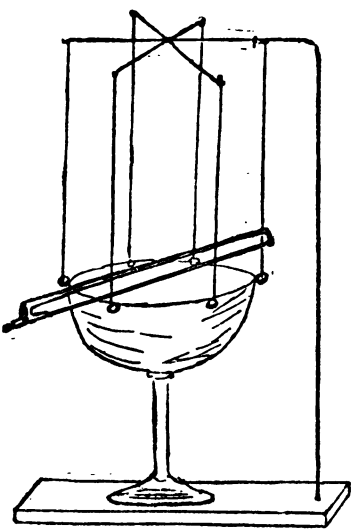


FIG. 1.

minute and so rapid are they; but as the waving glass touches the little balls, these take up the vibrations, and, being free to move, fly away from the rim of the glass, returning thereto after having performed an excursion, to be again driven off by succeeding wavelets. The louder the sounds produced the larger will be the oscillations; so we learn from this, that although the *loudness* of a sound depends on the amplitude or size of the waves set up, yet the "pitch," or relative shrillness or lowness, of the resulting tone has nothing to do with the size of the waves, but only with the rapidity with which they succeed one another. Hence, whether we bow lightly or heavily, the note given by the glass will be the same, though its loudness may differ. If the experimenter is able to sing, he will find that when he has once recognised the note given by the glass under the influence of the bow, he can get the glass to vibrate, to emit its note, and to cause the little balls to oscillate, by simply singing loudly that same note in the immediate vicinity of the champagne glass. In fact, if the singer be gifted with a powerful voice and a sufficiently correct ear to sing *exactly* the fundamental note of the glass, it will be possible to make the glass enter into such a violent state of vibration under the sympathetic influence of the air waves emitted by the singer as to cause it to shiver to pieces. In performing this last experiment, the operator will do well to remove the suspended balls,

which, by checking to a certain extent the vibrations set up, might render its success problematical.

§ 2. The fact that vibrations give rise to sound is easily proved by means of Savart's wheel, an instrument which admits of the number of vibrations producing a given sound being accurately counted. It consists of a toothed wheel and a driving-wheel mounted on spindles, each being sup-

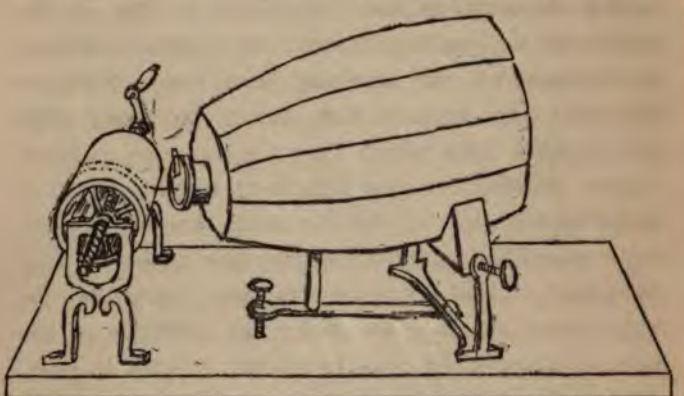


FIG. 2.

ported on bearings, and playing between the sides of a channel made in a four-legged bench. By a band or gut the motion imparted to the driving-wheel is transmitted to a small pulley on the shaft of the toothed wheel. The number of teeth on the toothed wheel is noted, as also the number of revolutions this makes to one revolution of the driving-wheel. By means of a speed counter, it is easy to ascertain the rate at which this latter is being

driven. A piece of thin but elastic card is held across the opening in the bench, in such a position with regard to the toothed wheel as just to engage in the teeth when the wheel is moving. Every tooth, as the wheel goes round, lifts the card up and lets it fly back again; in other words, causes it to make one complete vibration. Knowing the speed at which the driving-wheel is being run per second, and the ratio between the speed of the driving-wheel and the driven one, it will be easy to calculate the number of vibrations required to produce any given note. By this means it is found that 256 vibrations per second give the note ; that 512 set up the sound we know as .

§ 3. Perhaps one of the most interesting devices for showing the vibrations of a sounding body is Léon Scott's "Phonautograph," which was made known by its inventor as far back as 1856. We shall give here a brief description of this instrument, as it contains the germs of the phonograph. It consists practically in a kind of cask made of plaster of Paris. One end (the upper) is left open to receive the sound; the lower end is partially closed with a solid bottom, in the centre of which is a smaller circular aperture, into which fits a rather short piece of brass tubing, about 4 ins. in diameter. By means of a ring, a flexible membrane is stretched more or less lightly over this tube, like the parchment head of a drum. Near the centre of this stretched membrane is fastened, by

means of a little sealing-wax, a hog's bristle, which acts as a stylus or "pen." Any sound made near the open mouth of this instrument sets up vibrations in the air, which communicates its vibrations to the stretched membrane, the hog's bristle partaking at the same time of similar vibratory movements. If now, just in front and within reach of the hog's bristle, be placed a cylinder covered with a turn of lamp-blacked paper—this cylinder being capable of rotating on its axis by means of a handle, and at the same time of travelling forwards in obedience to a screw-thread cut on the same axis—we shall find that if no sound be received by the phonautograph, the hog's bristle simply produces a spiral line on the black paper as it passes under it; but if a note be sung, or any sustained sound be set up in front of the open end of the instrument during the rotation of the cylinder, we shall get wave-like lines, the character of

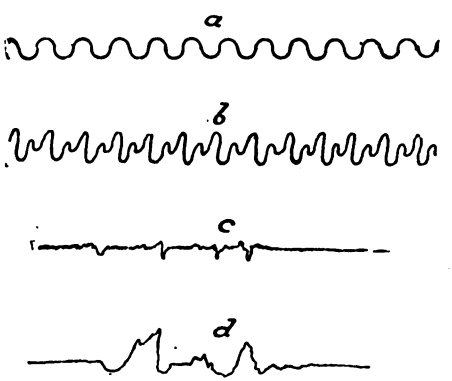


FIG. 3.

a.—A single note sung.
b.—A note and its octave sounded by two pipes simultaneously.
c.—The letter *r* rolled (as a cat purring).
d.—A sheet of tin struck with the finger.

the wave, etc., varying with the nature of the sound, but always similar for similar sounds. At Fig. 2 we illustrate this interesting instrument; and at Fig. 3 we give a few examples of the "sound writings" it produces on the blacked paper, as seen after this latter has been unrolled off the drum. We may therefore summarise as follows: All sounds are due to vibrations. All elastic bodies are capable of conveying these sound-waves to the ear—some bodies more quickly than others. We *generally* receive our impressions of sound through waves set up in the air, which waves strike on the drum of the ear, that is, in direct communication with certain portions of the ear which can respond to these vibrations, and convey the sensation to the brain. The *lowness* of a sound depends on the *slowness* of the vibrations; the shrillness upon their rapidity. Loud sounds are the result of big waves (whether slow or rapid); feeble sounds depend on the waves being small. When a sound is produced the air has waves set up in it, and these waves are capable of doing actual mechanical work proportionate to their amplitude (wave size) and their rapidity.

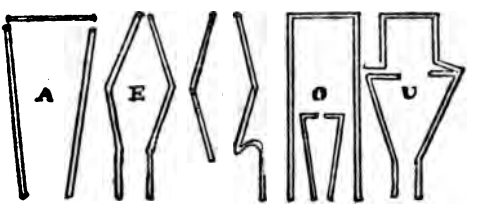


FIG. 4.

§ 4. The first attempts at constructing a talking

machine were made in 1779 by Mr. Kratzenstein, in response to an inquiry made and a prize offered by the Imperial Academy of Sciences at St. Petersburg, respecting the nature of vowel sounds. He showed that all the vowel sounds could be distinctly pronounced by blowing through a reed (the same as used in the mouthpiece of a clarionette or similar instrument) into the lower end of pipes having the forms shown in Fig. 4, in which the vowel sounds produced are indicated by corresponding letters placed near the pipes. It is needless to remark that the sounds are those of the vowels as pronounced by the Italians,* *i.e.*, the pure sounds, and not the compound sounds usually given to them in England. While he was thus engaged in these researches, a clever mechanician of Vienna, of the name of Kempelen, succeeded in making the first "speaking machine" (see Fig. 5) by adapting a reed to the narrowing portion of a funnel-shaped cavity, the capacity of this latter being capable of variation

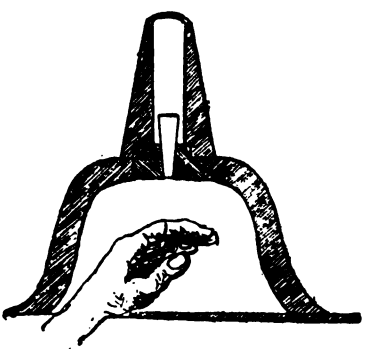


FIG. 5.

* A = Ah; E as in Egg; I as in In; O as in Or; U as in Puss.

by introducing the hand in different positions into the cavity while the reed is being blown into. Mr. Willis, of Cambridge, took up the idea, on somewhat similar lines, and found that by sliding a board to a greater or lesser extent over the mouth of the cavity he could obtain the whole range of vowels without using the hand (see Fig. 5A). He found that a similar result could be attained by adapting tubes of different lengths to the reed. Kempelen later on varied the shape of the cavity, and finally settled upon a hollow oval box, in the shape of two jaws, made of indiarubber. To this "mouth" was added a "nose" made of two tin tubes, which communicated with the mouth. When both these tubes were open, and the mouthpiece closed, a perfect M was sounded on blowing; and when one was closed and the other left open, an N was the result. He was at last successful in producing a machine, in the form of a box, about 3 ft. long, and of nearly the same height, covered with cloth, by means of which, on manipulating the bellows and the slides, he was able to produce any single word, or even sentences such as the following: Vous êtes mon ami, Je vous aime de tout mon

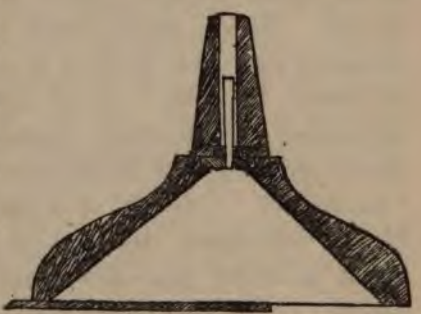


FIG. 5A.

cœur, Venez avec moi à Paris, Romanorum imperator semper Augustus, etc.*

§ 5. Ingenious as were these devices, they were so complicated in their attempted imitation of the human vocal organs, with the necessary supply of air to cause them to act, that even if they had been brought to perfection they could never have come into general use. Besides, they were incapable of *recording* or taking down automatically any given sound, speech, or song; hence their utility was very limited. Nearly eighty years elapsed before any discovery was made tending to perfect the speaking machine. In 1860, Reis, of Frankfort, devised an instrument which could reproduce, *at a distance*, sounds emitted near to its transmitting end. This "transmitter" consisted of a diaphragm made of a film of collodion † stretched on a drum-head: any sound occurring near this membrane was found to produce oscillations on its surface, corresponding in number, in rapidity, and in amplitude, to those of the waves of the sound which set them up. Attached to some portion of this membrane was a light lever, which under the influence of these oscillations alternately made and broke circuit between a galvanic battery and an electro-magnet placed at the distant end. In obedience to the electric currents thus sent

* See "Letters on Natural Magic," by Sir David Brewster, p. 207, *et seq.*

† Collodion is gun cotton dissolved in ether. If poured on glass and allowed to dry it forms a thin transparent skin.

along (which were similar to the sound waves) the electro-magnet either attracted or failed to attract its armature. Connected to this armature, or forming part of it, was a "wing" or thin plate, which oscillated or vibrated precisely as did the armature. In so doing it set the air in its vicinity in vibration, and as these vibrations were similar in every respect (except, perhaps, in amplitude) to the sound waves originally impinging on the diaphragm, so that the sound was reproduced, at the distant end, alike in every point except that of *loudness*, which is dependent, as we have already seen, on the amplitude of the waves. This was the original "telephone." Improvements rapidly succeeded one another at the hands of different experimenters as Elisha Gray, Graham Bell, etc.; and the receiving armature soon became altered to a thin disc of elastic, iron, or sheet steel, known as "ferrotype," * which, under the influence of the undulatory currents of electricity passing around the pole or poles of the magnet placed near it, entered into vibratory motion. That keen observer, T. A. Edison, in following out some experiments he was making with regard to reproducing automatically a message sent by the Morse system into a diaphragm with a stylus attached, noticed that the stylus moved with sufficient force to prick his finger. He found he could get indentations with a needle attached to

* Formerly much used in the production of direct positive photographs.

the ferrotype diaphragm on paper, tinfoil, etc., which were capable of reproduction as sound vibrations by passing them under a stylus connected to a similar diaphragm. He at once saw that he could vibrate a diaphragm directly by the voice, and that if *this* diaphragm were furnished with an indenting or cutting stylus, it could be made to trace a record of its vibrations on a cylinder of suitable material, which was at the same time caused to rotate spirally under it. Further, he perceived that if the same "record," or indented cylinder, were caused to rotate under a similar diaphragm, furnished, however, with a smooth stylus instead of a cutting one, the indentations would, in their turn, cause the diaphragm to vibrate, and thus reproduce the sound of the voice, etc., that originally set up the vibrations. Such was the origin of the first really efficient machine, capable at once of writing any sounds emitted in its vicinity, whence the name phonograph (from "phōnē," a sound; and "graphein," to write), and also of reproducing similar sounds from the writing or "record," thus inscribed; for which reason it is also called "graphophone," or *writing sound.*

§ 6. The following description of the simple hand-driven form of Edison's original phonograph, invented by him in 1877, will be found interesting, and will elucidate the principle of the instrument so thoroughly as to enable the reader to appreciate the improvements that have been subsequently introduced. The original phonograph, which was deposited in the

British Patent Office Museum at South Kensington, consists of a brass drum with a fine spiral groove running around it for its entire length. Over this is placed, and drawn rather tightly, a sheet of tinfoil, on which the indentations made by the needle, attached to the diaphragm, are registered. The shaft which carries this drum, and which is fitted with a cranked handle to enable it to be rotated, has a screw-thread along its surface, of the same number of turns to the inch as that on the drum itself—so that the drum is carried forward the distance that lies between one thread and its neighbour with one revolution of the handle, since the shaft runs in a bearing which has a corresponding female screw on its interior surface. We present our readers at Fig. 6 with an illustration of this the first form of phonograph. As the reader might find it interesting and instructive to make an instrument on these lines, we give the following details of one perfected by Mr. Shelford Bidwell, and described by him some twenty years ago in the pages of *The English Mechanic*. The essential portions are a brass or

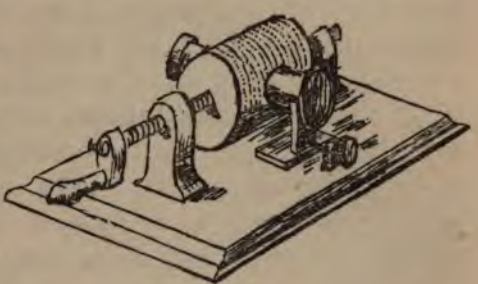


FIG. 6.

hard wood cylinder, 4½ ins. in diameter and 4½ ins. in length; an iron or steel spindle, ⅜ in. in diameter, and 16 ins. long. This spindle should have a screw cut upon its surface of eight threads to the inch, and at one end should be fitted with a winch handle (such screws, already made, can be purchased at the tool shops, as they are used for clamps and for carpenters' benches). At the same time that this screw is obtained, a couple of nuts fitting accurately on the thread of the screw should be secured, as these will be inserted into two blocks (B and C) which are to serve as the bearings for the cylinder and its spindle. The wooden cylinder should be mounted in the centre of the shaft, and secured thereto either by two thin nuts, driven close against the heads of the cylinder, or by a key and key-way. The cylinder should naturally be turned up on its own shaft after thus mounting, to ensure its running truly concentrically. This being done, two hard-wood uprights are made to support the spindle, 1¼ ins. in thickness, about 3½ ins. in height, 3 ins. wide at the bottom, diminishing to 2½ ins. at the top. At 2½ ins. from the base a hole is put through these two uprights to allow the spindle to fit in easily; and centrally with these holes the two nuts fitting on the spindle or shaft must be let in the wood and fastened thereto, as *bearings* to the spindle. Each of these uprights has two holes in its base for the purpose of fastening it down to the base-board. The cylinder, spindle, and bearings, being completed, eight pieces of wood must

be prepared of the following dimensions: A is 12 ins. long × 9½ ins. × 1⅛ ins.; D is 5½ ins. × 5½ ins. × ½ in., and has a circular hole 2¾ ins. in diameter cut in its centre; E is similar to D, and F is likewise similar to D, except that its central hole is only 1 in. in diameter; the pieces G and H are both 5½ ins. × 2½ ins. × 1½ ins.; I and K are both 8 ins. × 2½ ins. × 1½ ins.; B and C, of which we have already made mention, constitute the supports for the bearings, one of which is shown at our Fig. 7. The position of the other wooden parts is indicated by letters corresponding to them in Figs. 8 and 9. The uprights (B and C) are fixed near the ends of the base-board (A) by means of 2½-in. screws; D and F are screwed together (see Fig. 8), and the two are then fixed perpendicularly upon G; G is joined to I by a pair of hinges. The two ends of I are screwed to the base-board, but the two holes in I are ⅛ in. larger in diameter than the screws which pass through them. In order that the screw-heads should not tend to slip through these larger holes, two thin iron

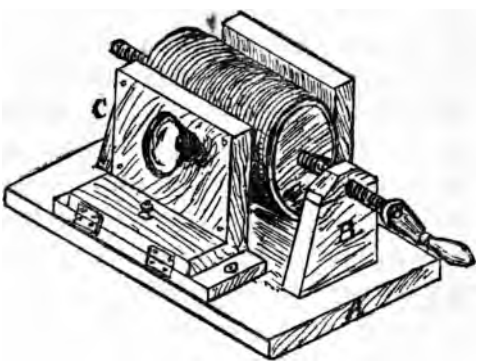


FIG. 7.

washers, about ¾ in. outside diameter, are slipped up the shank—the object of this arrangement being to allow a certain amount of play in the board (I) for the purposes of adjustment. When properly adjusted, the screws may be tightened, and the board firmly fixed in position. As D and F were fastened vertically to G, in like manner E is attached perpendicularly to H; H is hinged to K, and K in its turn is fixed to the base in precisely the same manner as was I. Through the middle of I is passed a brass screw-bolt, the square head of which is fixed in I. The screw goes through elongated hole in G, and is fitted with a round milled brass nut. Screw-bolts of this description are used for fixing the expanding bodies of photographic cameras, and may be had from most dealers in photographic accessories; H and K are fitted with a similar bolt. Two rather stiff pieces of steel spring are attached to the ends of I, and extend for a little way underneath G; these springs tend to separate G and I, or rather to cause G to turn backwards like the lid of a box when opened. The nut, of course, works against the springs. When it is screwed up tightly G and I approach, and may be made almost to touch each other. When the nut is loosened, the spring causes G to rise. Very delicate adjustment is thus rendered possible. To a like end H and K are fitted with similar springs.

The diaphragm which is to receive the voice or sound is fixed over the circular hole in D, as shown in Fig. 8. It consists of a circular plate of very thin

iron, 4 ins. in diameter. "Ferrotype" plate will answer the purpose very well. The point, or graver, which serves to indent and produce a record of the vibrations is made from a piece of very hard steel wire, or of knitting-needle, about $\frac{1}{20}$ of an inch in diameter. It must be very hard; one that can be bent is of no use. Holding such a piece of steel at an angle of about 30° on an oilstone, a sharp point is ground on it, polished, and then cut off with a file. This has to be fastened to the centre of the diaphragm. As this latter must not be buckled, the following plan should be adopted: The ferrotype diaphragm should

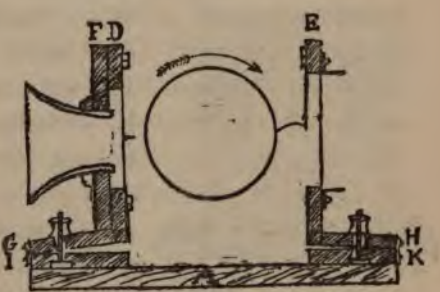


FIG. 8.

be lightly scraped at the centre while resting on a flat sheet of glass, just sufficient force being used to remove the japan, but not to bulge the disc. The small piece of knitting-needle should be held by its pointed extremity with a small pair of pliers, and the exposed end "tinned" with a little solder, with a tinman's bit, so as to leave a globule of solder adhering. The clean spot in the centre of the ferrotype plate can now be touched with a mere drop of soldering fluid, and by holding the disc at a little distance over

the flame of a spirit-lamp, with the soldered end of the steel point held against the bared spot on the disc, the solder is caused to run, and make a firm connection between the graver and the ferrotype disc. Only sufficient heat must be applied to melt the solder; any excess would buckle the plate or blister the japan. Care must be taken that the point stands quite perpendicular to the ferrotype disc. When this has been successfully executed, the disc should be well washed in cold water, so as to remove any soldering fluid which would set up rust. For the same reason it would be advisable to put a little oil on the steel point and the disc, any excess being carefully wiped off. The diaphragm is fixed in its place over the circular hole D by means of a brass flange (like a camera flange), 4 ins. in outside diameter, with a $2\frac{3}{4}$-in. opening; four screws can be used to hold it down. This completes the recording diaphragm. The reproducing, or speaking, diaphragm is made of parchment-paper similar to that used for covering jam-pots. It must be 4 ins. in diameter, and goes over the hole in E on the side further from the cylinder. The parchment-paper should be moistened, any excess of water being removed by blotting-paper, then gummed round the edges, applied to its place over

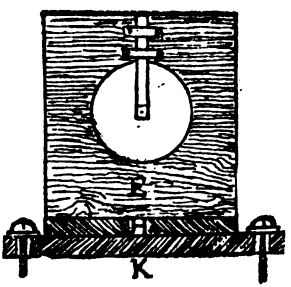


FIG. 9.

the hole and made to stick down quite smoothly, when it will be found to dry, stretched as tight as a drum.

The second, or speaking point, is made precisely like the first, except that it may with advantage be a little sharper. It is not attached directly to the paper diaphragm, but to a steel spring, which can be seen at Figs. 8 and 9, and consists in a piece of main-spring $\frac{5}{16}$ in. wide and $2\frac{7}{8}$ ins. long. Two small brass straps just over the hole E (Fig. 9) hold this in its place. This must be bent so much that its end when free is just $\frac{5}{8}$ of an inch distant on the plane of E. This spring should not be too stiff, since it has to follow the indentations made by the recorder. The point will be fixed to the end of this spring, in a similar manner to which the recording-point was fastened to the ferrotype disc; the operation, however, will be easier, as there is no danger of buckling or overheating. Washing and oiling, however, should not be neglected, otherwise the point will soon rust. In order that the vibrations of the spring may be communicated to the parchment-paper diaphragm, a loop of sewing-silk is attached to the centre of this latter by means of a little $\frac{1}{4}$-in. square of court-plaster. The length of the loop must be such that, when it is drawn over the spring just above the point, the end of the spring may be nearly in the plane of E. The spring is thus caused to draw the paper drum even tighter than it was before, and its inner surface is rendered slightly convex. All this should be done

before the two brass straps are finally screwed down tightly. It will be noticed at Fig. 8, on the outside of E, that a flange grips round the edges of the paper drum, being held thereto by four screws. This flange has a rather wide rim, on which is slipped a paper resonator. This is a cone made of several thicknesses of stout drawing-paper—its length is 18 ins.; its diameter at the smaller end, where it should be thickened and have parallel sides, is $2\frac{1}{8}$ ins., and at the large end 7 ins. A wooden mouthpiece, like that used for speaking-tubes, or telephones, is inserted in the hole F (see Fig. 8).

The instrument is now complete, but it will require careful adjustment before it can be used. In the first place, the screws which attach it to the base must be loosened, the milled nut on A screwed up tightly, and the piece I shifted about until the point on the iron disc is exactly in the middle of one of the grooves on the cylinder, and barely touches the bottom of it. Then the screws must be tightened, and this part of the apparatus finally adjusted. The same process is repeated on the other side; but in this case the adjustment is not quite final, as will hereafter be seen.

The next thing is to procure suitable tinfoil. This should be rather stout—about 15 square feet to the lb.—and should be cut into pieces $14\frac{1}{2}$ ins. × $4\frac{1}{2}$ ins. Before putting a tinfoil on the cylinder the two nuts are removed, and the diaphragms turned back out of the way. A little gum brushed along one end of the

tinfoil will be sufficient to keep it firmly in its place; the join must be carefully smoothed. The diaphragms are then turned back to their places, and the nuts screwed on. The nut on G is screwed up just far enough to cause the point on the iron diaphragm to touch the tinfoil very lightly. The handle is then turned about a quarter of a revolution, causing the point to make a short scratch on the tinfoil. The nut on G is then loosened, withdrawing the point from the tinfoil. The nut on H is then screwed up and another turn is given to the handle. If the scratch thus produced exactly coincides with the former one, well and good. If not, the screws attaching K to the base must be loosened, and K shifted about until absolute coincidence is attained. The utmost accuracy on this point is essential. The instrument may now be considered fit for use. Loosen the nut on H, so that the point on the spring may be well away from the tinfoil, and screw up the nut on G until the point on the ferrotype diaphragm may score a well-defined furrow on the tinfoil when the handle is turned. Turn the handle with as great regularity as possible at the rate of about one turn per second, or a little slower. Speak loudly and distinctly into the mouth-piece, putting the mouth as near as possible to it, without actually touching. When you have finished, withdraw the point by loosening the nut G, rotate the handle backwards until the cylinder is in its original position, then screw up the nut at H until the second point presses lightly, but steadily, upon the bottom

of the furrow. Now put on the paper resonator, and turn the handle at the same speed as before. If the adjustments are perfect, the results will be astonishing. If nasal sounds are given, the ferrotype diaphragm may be separated from its brass flange by an india-rubber ring.

§ 7. It soon became evident that the arrangement described in the last few sections, although fully competent to take up and to reproduce sounds emitted before its trumpet or "bell," was not one which lent itself readily to the production of many durable "records,"* or to the reproduction of sound from these records when made. Firstly, because the tinfoil could not be easily removed from the grooved cylinder, or replaced thereon, without risk of grievously distorting the tinfoil and thereby altering the character and falsifying the indentations produced on its surface by the indenting point, or "recorder." Hence it became necessary to have a separate cylinder, leading screw, and crank, for every new record desired. Secondly, because the motion imparted by hand is likely to be irregular, and therefore to alter the "pitch" of the music, etc., in a most disagreeable and inconvenient manner. Hence endeavours were soon made to render the records removable from the cylinder, and replaceable thereon, without injury to themselves; also to impart mechanically, either by

* A record is that cylindrical or circular surface on which the sounds have impressed the indentations capable of reproducing *these* sounds.

an electro-motor or by clockwork, a steady rotary motion to the cylinder on which the desired records are placed. Edison, with his natural tendency towards electrical work, early perfected an electro-motor which has given great satisfaction, and was intended for use with the larger cylinders of 4 ins. diameter.

§ 8. To make a phonograph motor of this type the following parts are needed: Sufficient 7-in. cog ring laminations to make up an armature 1 in. deep (about 36 are usually employed). These laminations have 40 teeth or cogs round the periphery $\frac{1}{4}$ in. wide and $\frac{3}{4}$ in. deep, the web of the rings being $1\frac{1}{2}$ ins. deep, leaving a central aperture of 4 ins. diameter. A three-rayed brass spider, the rays of which can be bolted to three holes in the web of the punchings; a steel spindle about $\frac{3}{8}$ in. diameter keyed on the brass spider and passing through its centre. This spindle runs below on a cup-and-ball bearing, and above in a ball bearing somewhat like a bicycle bearing. The field-magnets of this motor consist of 4 pole pieces of cast iron about $2\frac{1}{2}$ ins. cube; these are yoked together by a cross-shaped casting or forging of round iron bars, joined at the centre, thus +, each being about $3\frac{1}{2}$ ins. long, by $1\frac{1}{4}$ ins. in diameter. The inner surfaces of the four square pole pieces are bored out, to admit of the armature rotating between them, with a clearance of $\frac{1}{32}$ in. only. In the centre of the cross thus formed is bored a $\frac{3}{8}$-in. cylindrical depression, in which are placed the balls on which the lower end of the spindle is to run. Across the top of a

diametrically opposite pair of pole pieces strides a brass bridge or bearing, in the centre of which are

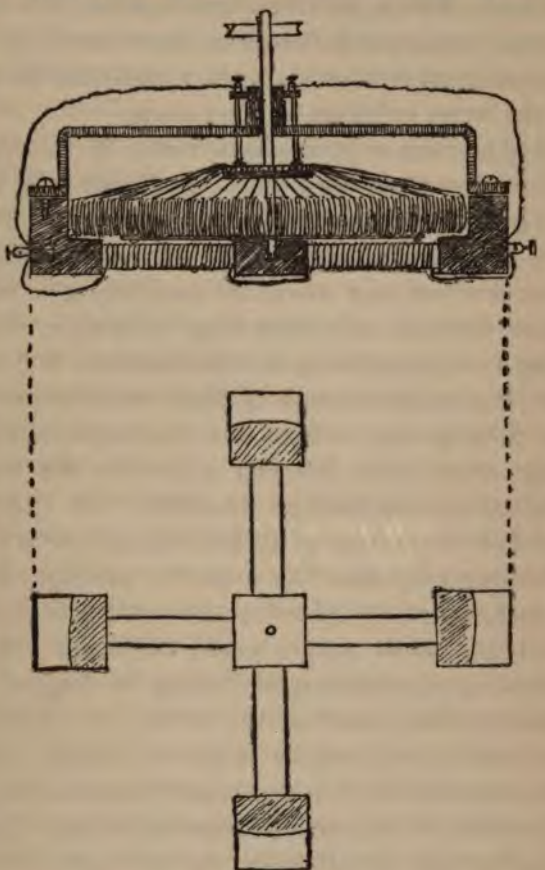


FIG. 10.

fitted the balls against which the upper portion of *the spindle* rotates.

This brass is a casting about 1 in. wide and ¼ in. thick, and bends four times at right angles so as to clear the armature and its commutator. As the armature has 40 teeth, so the commutator (which should take the shape of a flat copper disc) must likewise be divided into forty segments. The brush rocker may be conveniently made from an L-shaped piece of ebonite, fitting by a central hole and set screw, over the nozzle of the brass bearing through which the spindle passes. The brush carriers may be made from two short pieces of ¼-in. brass tube, passing through and attached to the extremities of the L-shaped ebonite rocker, reaching nearly to the surface of the commutator. The brushes themselves may be either small carbon rods sliding in the tubes and pressed down on the commutator by light spiral springs in the upper part of the tubes, or little cylindrical rolls of fine copper gauge placed in the same position and actuated in the same manner. The armature and the four cores of the field magnets must be "dressed" with silk to secure good insulation, and then wound with No. 20 d.c.c. wire. The armature will take about 2 lbs. of this wire, each space between each tooth and round the web being wound with about ¾ oz. of wire. The connection of wire to commutator will be as follows: Each space having been wound in the same direction, the end of the first coil is soldered to the beginning of the next, and so on all round; then the soldered ends of the commutator coils are each joined respectively to the

commutator bar just above it by small screws or by soldering. If it is intended, as above directed, to use only one pair of brushes, set at an angle of 90°, it will be also necessary to cross-connect, by insulated wires passing *under* the commutator, those bars of the commutator which are diametrically opposite one another. But if this task prove too difficult in execution, the same result may be obtained by using two pairs of brushes, which will then be mounted at the extremities of a cross-shaped ebonite rocker, the opposite pairs of brushes being, of course, metallically connected together. Each field-magnet core is wound with 1 lb. of the same wire, beginning the winding near the pole piece in the first, then passing on to the second, and winding always in the same direction, but starting near the centre of the second, again passing to the third, but beginning the winding at the end near the pole piece, lastly passing on to the fourth, where the start is made near the centre—so that the resulting magnet, when current is passing through, shall have its poles alternately N. S. N. S. The two free ends of the wire must be taken to terminals which are screwed into ebonite-bushed holes made in two opposite pole pieces. From under these terminals proceed two short spirals of wire, which serve to connect up the brushes to the field-magnet wires, because the motor must be connected up "in shunt."

The battery, accumulator, or other source of current, *is connected* to the motor by attachment of the two

wires proceeding from its poles to the holes in these same terminals. A current of 2 amperes at 2 volts pressure will generally give ample power to drive the phonograph—occasionally 4 volts may be needed. The most convenient source of current is certainly an accumulator. Our Fig. 10, which is partly in section, gives a good idea of the field-magnets and general arrangement of the Edison phono-motor. It must not be supposed that the above is the only form of electro-motor that is adapted to driving a phonograph. Any good self-starting electro-motor, fitted with a fairly massive ring or drum armature capable by its momentum of running smoothly, noiselessly, and at equal speed, will answer the purpose; and it is by no means necessary that it should have a four-pole magnet. Both in the Gillett and in the author's form of motor there are only two poles. The former has a Gramme ring armature, $2\frac{1}{2}$ ins. in diameter; in the latter the armature is larger, being 5 ins. in diameter. Those who are interested in the construction of electro-motors for this purpose, and would learn more of the constructional details than it is possible to give in a work of this kind, are referred to Gillett's "Phonograph," and to the author's various handbooks. When clockwork is employed, it takes one of two forms. In the one form a spring about $\frac{1}{2}$ in. wide, $\frac{1}{32}$ in. thick, and 5 ft. in length, is hooked on an arbor forming the winding centre, and inserted, after being coiled spirally, into a barrel about 3 ins. diameter and 1 in. wide, furnished with cog gearing

round one edge, the teeth of which engage in a train of two or more toothed wheels, so geared as to give the desired speed to the part or parts they are intended to drive. As it is of the highest importance that the motion of the cylinder should be perfectly steady and uniform, some form of governor

FIG. 11.

(or speed regulator) is actuated by one of the gear wheels. In another and simpler form the mainspring is not enclosed in a barrel, but hooked on the arbor at one extremity, and fastened to a round steel bar at the other. In this latter case the main driving wheel is geared at its circumference, and bears nearer its centre the ratchet and pawl arrangement, which

permits of the spring being wound up precisely as in the cheap American clocks. Fig. 11 shows the barrel form of clockwork, the gear wheels being visible at the end of the barrel near the left-hand corner of the frame. At Fig. 12 is depicted the open spring form. The gear wheel actuating both the three-ball governor and the little pulley, which, by a band or

FIG. 12.

gut drives the cylinder on which the records are slid, can be seen to the right of the frame holding the clockwork.

§ 9. The regulation of speed and its maintenance at a fairly uniform rate is affected either by means of a small fan or by a three-ball governor, which is attached to the third pinion shaft of the train of

clockwork. This is the shaft or spindle which rotates at the highest speed. The two-vaned fan is too well known to need any description here ; it is to be seen in every musical box, and, as is well known, acts as a damper by the resistance it presents to the air—a resistance which increases as the speed, which is therefore kept fairly uniform. In modern talking machines preference is given to the three-ball fly-wheel or governor. This consists of three thin steel springs, about 3 ins. long, $\frac{1}{32}$ in. thick, and $\frac{3}{16}$ in. wide. To the centre of each of these springs is affixed, by a screw passing through a small hole in the springs, a brass or other metal ball about $\frac{5}{8}$ in. diameter, weighing about an ounce. Each spring has drilled at both extremities a small hole, by means of which it can be screwed down to two triangular brass pieces. Both of these brass triangular pieces have holes through their centres, through which the spindle or shaft of the third pinion passes. One of these triangles is fixed rigidly to the spindle, at the extremity nearer the pinion ; the other is not fixed, but can slide freely on the pinion shaft. To this loose triangle is soldered a thin brass disc, about $1\frac{1}{4}$ ins. diameter and $\frac{1}{16}$ in. thick. As this disc forms part and parcel of the movable triangle, if this triangle moves forwards or backwards along the pinion shaft, the disc is dragged forwards, or pushed backwards, at the same time. Rising from some part of the base of the machine is a pillar bearing a screw which has a milled headed nut on the outside to enable the operator to screw it

in or out, and which presses at the other extremity (which passes *beyond* the brass disc just mentioned) against a spring, that when the screw is not tightened up, bears against the inner face of the disc, but which is pushed farther and farther from the disc in proportion as the screw is tightened up. The face of this spring, where it may come into contact with the disc,

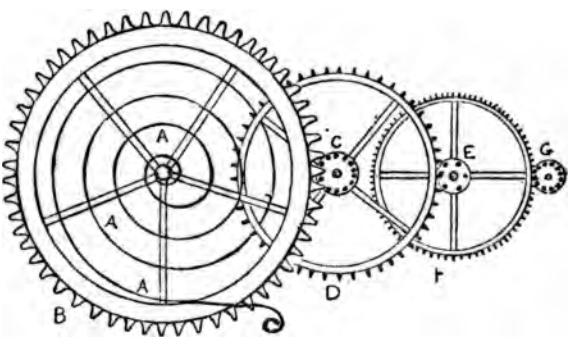


FIG. 13.

A A A, the Mainspring; B, First Wheel, 54 teeth; C, First Pinion, 12 leaves; D, Second Wheel, 48 teeth; E, Second Pinion, 6 leaves; F, Third Wheel, 84 teeth; G, Third Pinion, 12 leaves. This latter bears the governor on its shaft and drives the cylinder carrying the record.

is faced with wash-leather or any other similar soft material to prevent any grating sound from being heard. Sometimes the screw, instead of pressing against a spring, plays against one end of a small lever, pivoted at its centre; but, whichever system be adopted, the result attained is always the same, viz., to be able to vary the distance between the rotating disc and the little pad of wash-leather, which by its greater or lesser

friction tends to retard or even to stop altogether the rotation of the disc, and consequently of the clockwork. When the screw is retracted, the pad is pressing firmly against the disc, consequently the power of the mainspring is not sufficient to overcome this friction, and the mechanism is motionless. But on advancing the screw, the pad is removed some distance from the inner face of the disc, the mainspring asserts its power, and the train of wheels rotates.

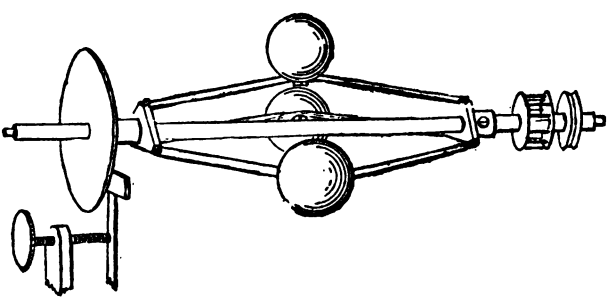


FIG. 14.

The three balls, by the centrifugal tendency they acquire in revolving, pull the springs to which they are attached; but as these latter are fixed at one end, they can only expand laterally by drawing the sliding triangle (with its disc attached) nearer the centre of the spindle. In so doing they bring the rotating disc again in contact with the pad, so that the farther the pad is kept away from the rotating disc by tightening the screw, the higher will be the speed at which the train of wheels, and therefore the barrel or cylinder

carrying the record, will run. At Fig. 13 we illustrate (in one line for clearness) the train of wheels, with the correct number of teeth as usually employed ; and at Fig. 14 we give an illustration of the ball governor device.

§ 10. It was soon found that the plan of keeping the stylus (whether of the reproducer or of the recorder) motionless, while the record itself was caused to travel along, was not only inconvenient, but capable of improvement. The same result can be attained, with far greater ease, by allowing the cylinder which carries the record (usually termed the "mandrel") to rotate on its spindle, without any lateral motion, while the recorder or reproducer (which are made interchangeable) are attached to a half-nut, that rides upon a cylindrical steel screwed rod, with, say, 100 threads to the inch. This rod or "governor-screw" is geared to the mandrel, and rotates at the same speed ; so that the half-nut, which supports the stylus, is carried forwards $\frac{1}{100}$ in. on the mandrel in one complete revolution. If this were the recording stylus, it is evident it would produce its indentations in spiral lines around the tinfoil, etc., placed on the mandrel ; if, on the other hand, the reproducing stylus were in position, it would travel in the spiral grooves thus produced by the recorder, and, in passing over the indentations, reproduce the sounds in due sequence. As, if the half-nut were a fixture on the screwed rod, it would be necessary to rotate both the screw and the mandrel in the opposite direction, when it were desired to return the stylus to its original or "starting" position, in order to avoid this inconvenience and loss of time, the half-nut is attached to a hinged

metal arm, that runs on a smooth steel rod, parallel to the screwed rod. This arm is fitted with a little pivoted lever, which when depressed raises the half-nut off the surface of the screwed rod, but which when lifted causes the half-nut to fall upon and engage itself in the threads of that screw. Hence, in the former case, the half-nut and its appurtenances (the recorder or the reproducer, and the horn or trumpet) can be slid from end to end of the smooth

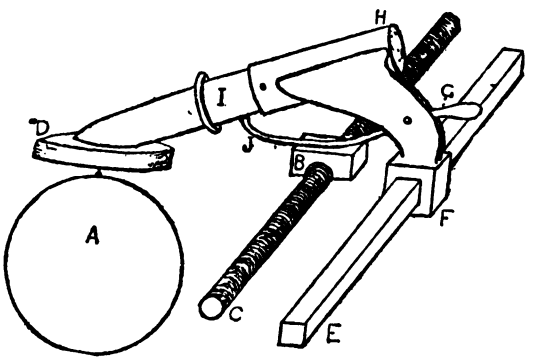


FIG. 15.

A—The Rotating Mandrel.
B—The Half-nut.
C—The Governer Screw.
D—The Reproducer.
E—The Guide-bar.
F—The Sliding Square.
G—The Lever.
H—The Nozzle, or Horn-carrier.
I—Rocking Tube to carry Reproducer.
J—Extension Lever.

bar without the stylus touching the record. At Fig. 15 we illustrate the principle of this action, which is capable of many minor alterations. On examining the illustrations given of the first forms of phonographs, it will be evident that little or no weight pressed on the surface of the tinfoil or other recording material. But in the modern forms, the *reproducer or* recorder, having to ride on the upper

surface of the rotating record, would press with a certain weight on the record, especially if, as is sometimes the case, the horn were attached directly to the stylus case, be it recorder or reproducer. The result of this would be, that the delicate surface of the record with its indentations would soon be worn down. To avoid this, a nozzle of metallic tube is attached rigidly to the sliding metal piece on which the raising and depressing lever works at right angles to the mandrel. This is inclined at an angle of about 25° from the horizontal, so that the end of the tube nearer the mandrel shall admit the stylus of the reproducer just clearing the surface of the mandrel when the reproducer is fitted on it. At the farther extremity of this tube the trumpet or horn is adjusted. It is necessary, in order that the reproducer may rest continuously on the record, notwithstanding the irregularities on its surface, that the recorder (or reproducer) should have a little play, upwards and downwards. For this reason the tube of the reproducer is not fixed rigidly to the nozzle; but this latter has a second smaller tube inserted in its nearer extremity, poised inside on two lateral pins. On this the neck of the recorder can be slid, with friction; from which it can be removed at will, and be replaced by the reproducer when desired. As the slight up-and-down play of these latter would allow the stylus to rest in the groove of the record, even when the lever that actuates the half-nut is depressed, an extension of the same lever is usually fitted, that, engaging in the lower portion of the little movable tube or collar, raises it sufficiently to allow it to clear the surface of the record when the lever is raised.

Anyone acquainted with the arrangement of the leading screw, split nut, and saddle, of a screw-cutting lathe, will readily recognise the similarity of the devices used to secure the traversing motion.

§ 11. The portions that next received improvement were the mandrel and the records. It is evident that, using the grooved cylinder for a mandrel, with the tinfoil wrapped round it, to receive the impressions produced by the stylus, either a new mandrel would be required for each record taken, or else that the tinfoil, with its minute indentations, should be stripped off the surface of the mandrel—a procedure that must inevitably ruin the record itself. For this reason the form of the mandrel was soon changed from that of a grooved cylinder to that of one perfectly smooth, slightly tapering from the end at which it is geared to the driving mechanism, towards the free end, on which the record could be pushed on. Two standard sizes have been pretty universally adopted for these mandrels: in the ordinary type they are $4\frac{1}{2}$ ins. long by $1\frac{3}{4}$ ins. in diameter at the larger extremity, tapering to $1\frac{11}{16}$ ins. at the smaller end; while in the larger instruments, known as the "grand," or "concert" type, the mandrel is 6 ins. long, by $3\frac{3}{4}$ ins. at its larger, and $3\frac{11}{16}$ ins. at its smaller, end. The material on which the record was to be produced next demanded attention. Tinfoil was soon discarded, as being too soft to admit of handling for removal or replacement. These "blanks," as they are termed, were first made of white wax, cast of a cylindrical form, in a mould having an inside diameter of 4 ins. in the larger, and 2 ins. in the *smaller, types.* Up the centre of the mould is a core

of the same diameter, and tapered like the mandrel of the instrument which the "blanks" are destined to fit. In order that the "blank" may cling slightly to the surface of the mandrel when in use, the central core of the mould is not smooth, but has a wide channel arranged spirally round its surface. Partly because of this, and partly because the wax contracts considerably in cooling after being cast, it is necessary to make the core in several pieces, so that on drawing out a central wedge, when the wax is just setting, the side pieces of the core can be removed. The blank being thus prepared, it is to be mounted on a suitable mandrel between the centres of a lathe, and its surface gone over with a very light cut, so as to leave a perfectly level and polished surface. Such blanks were found to be very superior to tinfoil. Firstly, because their softer surface permitted them to take a deeper record; and, secondly, because, with care, they could be removed from their mandrel, replaced by others, and used again several times. Still, wax alone was soon found to be too brittle, and also too soft. Mixtures of other substances with wax were then tried; but the substance that seems to give the best results is a kind of resinous lead-soap or plaster, very closely allied to the lead-plaster of the apothecary. No two makers of blanks use exactly the same composition, and they are all very careful to keep the ingredients and their proportions as secret as possible. We give here, as the result of our experiments and analyses, a few recipes for compositions suitable for making these blanks. By varying the proportions, the experimenter can produce a composition of such a degree of hardness or softness as shall be most

fitted for the purpose he has in view. The first contains no lead, and can be made of any desired degree of hardness by increasing the amount of resin. Take clean resin (colophony) ½ lb., good paraffin wax ½ lb. Melt the resin carefully without burning, over a clear fire, in a well-glazed pipkin. When melted add the wax. Stir continuously until the paraffin is entirely melted and incorporated with the resin. To make the second, we shall require some *lead-plaster*; this can either be purchased from the chemist, or made as follows:—We mix ½ lb. of oxide of lead (litharge) with 1 lb. of olive oil, and ½ pint of water; place this mixture in a pipkin or other suitable vessel that will stand the heat, place it upon a gentle fire, and keep it simmering, with constant stirring, until all the water has evaporated. We then take of this lead-plaster ½ lb., resin 3 ozs., hard soap 1 oz. These are melted together, beginning with the resin, the soap being added last. In order to incorporate the mass, it must be constantly stirred. A third, and very good composition, consists in—Burgundy pitch 26 ozs., frankincense 13 ozs., resin 4½ ozs., yellow beeswax 4½ ozs., olive oil 2 ozs., and water 2 ozs. These must be melted together at a gentle heat, with constant stirring, until all the water has been driven off. A composition which gives satisfaction to amateurs, as it takes the impression very easily, is made by melting up ordinary "carriage candles" (stearine, not paraffin) with about one-eighth their weight of well-dried, finely-precipitated chalk, the same as is used for tooth-powder. A composition recommended by Mr. Suggett, but which the author has not tried, consists *in 1 lb. ozokerite* and ¼ lb. Carnouba wax (also called

"vegetable wax"). This composition is said to give very good results, but requires most careful cooling after moulding, as it is apt to crack, if the change of temperature is sudden. Perhaps the most satisfactory of all the compositions is made by preparing a stearate of lead, by the addition of litharge to melted stearic acid, and then adding gradually this compound to a mixture equal parts of resin and paraffin wax, in a molten condition. Portions of the compound should be tested for hardness, by allowing a drop or two to set on a cold piece of glass, before adding more stearate of lead, until the mixture becomes sufficiently hard to resist the pressure of the nail, but soft enough to cut up, with the slightest touch if the sharp edge of the head of a pin, be lightly drawn along its surface. If of the proper consistency, the composition should not break up into fine powder (which would point to its being too hard and brittle), but rather produce a very fine curl, like a minute shaving. Except for the purpose of experiment, we do not recommend the amateur to make his own blanks, since the present price of these is so moderate that they are not worth making. If, however, the experimentalist decides upon trying, he will do well to remember that it is advisable to put a single turn of oiled blotting-paper around the inner core of the mould, as this greatly facilitates the extraction of the finished blank. If this precaution is adopted, it will be unnecessary to turn the spiral channels on the core, as it will be sufficient to put one turn of the oiled blotting-paper round it, and then over this layer to wind spirally another strip of blotting-paper, also oiled, about $\frac{1}{4}$ in. wide, from one end to the other of the core, leaving a space of about $\frac{1}{4}$ in. between each spiral.

§ 12. Many improvements have been introduced in the form and materials employed for the diaphragms known as the "recorder" and the reproducer. Although the very thin sheet steel, known as "ferrotype" plate, long held its position as the vibrating membrane (and is still very good for certain effects), it has gradually been largely superseded by thin aluminium, by very thin sheet glass (about $\frac{1}{250}$ of an inch in thickness), and by *mica*. The recording stylus is now seldom made of steel, except only in the very

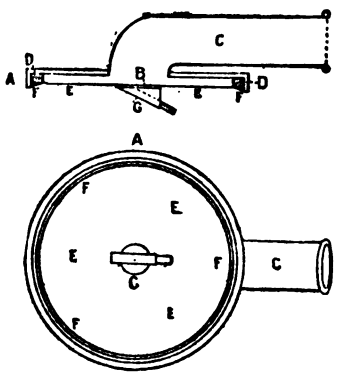


FIG. 16.

FIG. 17.

commonest forms of recorders; but is usually made of a small cylindrical piece of sapphire, ground so as to present an angle of about 60 degrees with the surface of the blank, and then polished. As in nearly all modern instruments the entire recorder rides on the top of the rotating blank, instead of being placed on one side, the complication of spring or weight adjustments is done away with; and excepting the weight of the little case which contains the diaphragm or *membrane, with* its cutting stylus, nothing is required

to keep the stylus against the surface of the blank. Occasionally, however, provision is made, by means of a lever carrying an adjustable weight at one end, to increase or decrease the pressure of the recording stylus on the blank, or of the reproducing stylus upon the record. Our Fig. 16 gives a sectional and perspective view of a good modern type of recorder. Here A represents a light circular shallow box, either of aluminium or other light metal, or of ebonite, usually about $1\frac{1}{2}$ ins. outside diameter, and $1\frac{3}{8}$ ins. inside. The depth of this is about $\frac{3}{32}$ in. In the centre of this shallow box is an aperture (B) nearly $\frac{3}{8}$ in. in diameter, over which is a bent tube (C), into which this hole opens. The farther extremity of this tube is made to fit with friction on the nozzle which carries the horn (see Fig. 15, I). An indiarubber ring, fitting exactly in the box, is cemented by a little seccotine round the inner edge of the box, at DD. On this is placed, perfectly flat, a thin disc of glass (E), from $\frac{1}{150}$ to $\frac{1}{200}$ of an inch in thickness, and a shade less in diameter than the inside of the box. This thin glass diaphragm, or "membrane," is fastened in its place by running a little softened beeswax all round the extreme edge, or by painting round it with the least possible trace of indiarubber solution. This is shown at FFF. A small strap of thin brass or german silver sheet, about $\frac{1}{100}$ in. in thickness, is bent at its centre tightly round a little circular rod of polished sapphire so as to grip it firmly. This sapphire should be about $\frac{1}{32}$ in. in diameter, and about $\frac{3}{8}$ in. long, and cut off perfectly sharp at right angles to its length, so as to form a good cutting edge. The pieces of the strap that project downwards from where the metal grips the sapphire are now bent at right angles, but in such

a manner as to allow the sapphire rod to form an angle of about 45 degrees with the feet thus produced. The ends just bent are then cut so as to form a little circular foot about ¼ in. in diameter, which is then fastened to the centre of the glass diaphragm at G by the aid of a little seccotine. The cutting edge of the sapphire rod must point towards the tube (C) that fits on the horn. The sapphire stylus, on being finally placed in position, should be fastened into the channel made by bending the brass by means of a little seccotine or similar cement. The sapphire, owing to its hardness, is much more durable than steel; but for experimental purposes, or where the stylus can be frequently changed, a short piece of fine knitting-needle ground at right angles to its length forms a very good substitute. Of course it must be hardened. This completes the recorder. Fig. 17 illustrates a very favourite form of recorder, in which the glass diaphragm is mounted in an ebonite case, which is solid except where it is joined to the tube. The tube in this particular form projects from the side instead of from the top of the case.

§ 13. The reproducer next demands attention. In general appearance it resembles the recorder described in our last section, except in the form given to the stylus. In the recorder, when using a stylus of the pattern before mentioned, it is evident that the tracing produced thereby must take the shape of a furrow forming part of the arc of a circle, with indentations along its sides and bottom, due to the vibrations of the diaphragm. Hence, to take up all these delicate tracings, and at the same time *not to injure* them, it is absolutely necessary that

the outline of the reproducing stylus should be circular, and have no sharp edge. For this reason the shape now almost universally adopted (for phonographs) is that of a perfect sphere, the section of which should be a trifle smaller than that of the stylus of the recorder. In order to obtain an intelligent idea of the principles of construction and of the action of the reproducer, the reader will do well to *make* for himself the simple form now to be described. By doing this he will obtain a clear insight of the requirements, and will be able to follow the modifications that have been introduced into this most important portion of the phonograph much better than he could

FIGS. 18 AND 19.

by any other means. For this purpose he will require a shallow circular box of thin metal about $1\frac{3}{4}$ ins. outside diameter, $\frac{1}{16}$ in. deep. This can either be turned up on the lathe from a piece of sheet brass of that thickness, or else "spun" from sheet brass about $\frac{1}{16}$ in. thick. The inside of this box should be $\frac{1}{16}$ in. deep, and the shell need not exceed $\frac{1}{32}$ in. If the operator has not the convenience for turning up such a box he will find a very good substitute in the lid of a small "Globe Polish" box. These are made of tinned iron, and the small sizes are exactly $1\frac{3}{4}$ ins. in diameter. As such a lid is deeper than required it can be ground down by rubbing it, edge downwards, on a flat stone, with a little fine sand and water, until

the depth inside is reduced to about $\frac{1}{16}$ in. In whichever manner this shallow box has been produced it will be necessary to put through its centre a circular aperature a shade under $\frac{3}{8}$ in. in diameter. This can be done on the lathe, in the case of the brass box, or may be punched out with an ordinary punch (laying the lid on a block of lead while striking the punch) in the event of the tinned iron cover being used. At Fig. 18 we represent the box at this stage. In order to be able to adapt this to the end of the horn or trumpet it will be necessary to fit on it a piece of thin brass tube that will just enter with friction into the nozzle of the horn. The size is generally a bare $\frac{1}{2}$ in.

FIGS. 20 AND 21.

in diameter. This thin tubing can be got from most metal merchants, and is known as "triblet" tube. A piece is cut off about $1\frac{5}{8}$ ins. in length, both ends are filed perfectly parallel, and then the tube is filed diagonally on one side until it makes an angle of 22 degrees with the horizontal, as shown at Fig. 19. This is now placed centrally over the hole in the box, on the outside thereof, with the diagonal cut downwards, and is then to be soldered neatly to it, as shown at Fig. 20, care being taken that the junction between the box and the tube be perfect all round, so that no air waves (on which the sound depends) can escape anywhere except up the tube leading to the horn. At Fig. 21 we give a sectional view of the reproducer at this stage of its development. The next

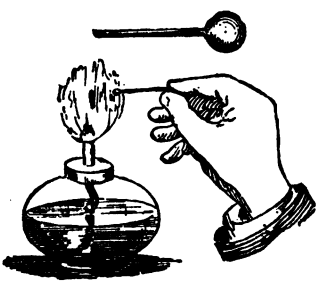
step is to fit it with its vibrating diaphragm, or "membrane." One of the best materials for this purpose is very thin glass (about $\frac{1}{150}$ of an inch in thickness is very suitable), and this can be purchased in discs, already cut to size, from the dealers in phonographs. Another excellent material, especially for the reproduction of band music, is "ferrotype" plate, which was extensively used by photographers for the production of direct positives. This is really very thin steel, about $\frac{1}{200}$ in. in thickness. In his experiments the operator will do well to commence with this, as, being less brittle than the glass, he will have less difficulty in manipulating it. He will place his reproducer box, rim downwards, on a piece of white paper, and by pressing it firmly upon this latter he will obtain an outline of the diameter of the inside of the rim. Cutting this circle out with a pair of scissors and using it as a templet he will lay it on the ferrotype plate and cut out of this latter a circlet of ferrotype, which will just drop into the box. Pains should be taken to ensure a perfect fit—neither so tight as to cause the ferrotype circlet to buckle, nor so loose as to allow it to wobble. This being done, the operator chooses a thin indiarubber ring, about $\frac{1}{32}$ in. thick, $\frac{1}{8}$ in. wide—one of the flat circular rings used for holding letters or other papers together will do admirably. The diameter of this must be such as will permit it to lie flat in the box (the ferrotype disc having previously been removed) with its outer edge touching the inside edge of the rim of the reproducer box all round. This indiarubber ring must be fastened down to the bottom of the box by smearing its surface with the slightest possible trace of seccotine, and then inserting it into the box. When it

has been pressed down and allowed to set, the ferrotype disc is placed upon it, glossy side uppermost. To fasten the ferrotype in its place the operator will knead a piece of beeswax between his fingers until it acquires the consistence of putty ; then he will, with the aid of a fine penknife, press a little of this softened beeswax all round the edge of the reproducer box so as to catch the extreme edge of the ferrotype disc, somewhat in the same way as a glazier fastens a pane of glass in the sash with putty. This little edging of beeswax should not extend more than $\frac{3}{32}$ in. in from the edge, and should be neatly finished

FIG. 22.

off. If the blade of the penknife be occasionally dipped in boiling water, and immediately wiped, it will, by its acquired heat, facilitate the adhesion of the wax to the ferrotype disc and to the rim. Another very good way of fastening down the diaphragm is by cutting a narrow ring of gummed paper, about $\frac{3}{32}$ in. wide, and of the same diameter as the outside of the rim of the box, and, having moistened this on the gummy side, to coax it to lie between the inner edge of the rim and the outer edge of the ferrotype plate. This can *easily be done* with the blunt side of the penknife.

There now only remains to fit the stylus. In first-class instruments this is made of some hard, precious stone, usually sapphire; in the cheaper ones it is made of glass. As with a little care the glass stylus will last for a very long time, and can be easily replaced when it gets worn, we will describe the manner of making such, premising that, should the operator desire to use sapphire, he can procure the little spherical beads, ready ground and polished, from phonograph dealers, at about 3s. each. To make a suitable glass stylus, the operator will need a piece of



FIGS. 23 AND 24.

glass tube, about 6 ins. long and $\frac{3}{16}$ in. in diameter. This he will hold over the flame of a spirit lamp, or small Bunsen burner, so that the central portion shall become red-hot. He will then pull the two extremities apart, so that a long, thin thread of glass is drawn out. Allowing this to cool, he breaks this thread at its centre. Taking one of the pieces of tube, he approaches the end of the glass thread to the flame, and allows it to melt, when it takes the form of a minute bead. By gradually approaching the thread to the flame, more of the glass can be melted, so that the size of the bead can be increased as much as may be

deemed necessary. As a rule, the little bead should not be more than $\frac{1}{40}$ in. in diameter, nor less than $\frac{1}{80}$ in. The bead, when examined through a lens, should appear perfectly spherical, and have a highly polished surface. Any roughness, or irregularity of surface, is inadmissible, and should ensure the rejection of the bead. The bead should then be broken off from the thread of glass, leaving, however, a stalk about $\frac{1}{8}$ in. long attached to it, to facilitate its "mounting" on the diaphragm. While the operator has the glass, etc., at hand, he will do well to make several of these beads, of varying sizes, as by mounting these, and trying them on the same record, he will learn much respecting the influence of the size of the stylus on the reproduction of the sound from the indentations. At Fig. 22 we show the manner of drawing out the glass thread, and at Fig. 23 the formation of the bead from the thread. Fig. 24 is a magnified view of such a bead, with its glass stalk. Having succeeded in producing such beads, the next step is to make a little support for the bead or stylus. This should be of such a form as to cause the diaphragm to vibrate as a whole, and not partially, otherwise "harmonics" will be set up, when the resulting sounds will be "tinny" and nasal. A very good form of support can be easily made by cutting a $\frac{3}{4}$-in. circle out of thin sheet brass, about No. 40 gauge, marking on this six equidistant rays from the centre, and then cutting out six segments, so as to leave a *star-shaped* figure, the rays of which should be about

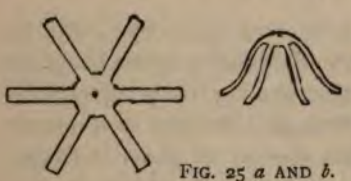


FIG. 25 *a* AND *b*.

$\frac{3}{32}$ in. wide. A minute hole, of the same size as the stalk of the glass bead, should now be drilled in the centre of this star. The rays of the star should then be bent downwards, equally all round, over the top of a thimble or similar rounded article, after which the extremities of the rays are to be bent outwardly for about $\frac{1}{16}$ in., so that the star can stand perfectly level on the six feet thus formed. The absolute level of these six feet is essential, as they must rest equally on the surface of the diaphragm, not only to ensure attachment thereto, but also that the whole of the

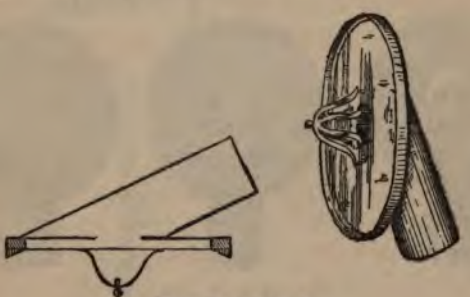


FIG. 26 *a* AND *b*.

diaphragm shall receive equal impulse from the six feet. The star-shaped support, both when first cut out and when afterwards bent, is shown at Fig. 25, *a* and *b*. This support must now be attached to the centre of the diaphragm by brushing a little thick shellac cement (made by dissolving shellac in the smallest possible quantity of methylated spirits of wine) on the lower part of the feet, and then pressing them on the diaphragm. The cement should now be allowed to set firmly, which will take an hour or two. A tiny drop of the same shellac cement should be

placed on the hole in the centre of the star, and allowed to evaporate a little until it is "tacky." Then taking the bead by the aid of a pair of fine forceps, the stalk thereof is pushed into the hole, so that the bead remains projecting above the level of the support. The sticky cement will soon dry, and hold the bead firmly in its place. One precaution is necessary in doing this, and that is, that no shellac cement be allowed to come in contact with the upper surface of the bead, which must be kept clean and brilliant. The reproducer is now complete, and

FIG. 26 *c*, *d*, AND *e*.

as soon as the cement has dried hard, which will take an hour or so if left in a warm, dry place, may be tested on a record placed on the phonograph. At Fig. 26, *a* and *b*, we represent this form of reproducer, which is known as the "Bettini," or "spider," in section and in perspective. Other forms are given to the support for the stylus; sometimes it takes the shape of a little thimble, about ½ in. diameter by ¼ in. in height; in others it is made to assume the form of a percussion cap, about ¼ in. diameter and ¼ in. high. Many materials have been used for diaphragms, of *which* we may mention mica, thin sheet steel,

celluloid, aluminium, ebonite, etc. Corrugated aluminium sheet, about $\frac{1}{250}$ in. in thickness, is said by many to give excellent results; but in the author's hands it has not proved a success: those which have given the best results are mica, glass, and steel, reduced to a thickness of about $\frac{1}{250}$ of an inch. At Fig. 26, *c*,

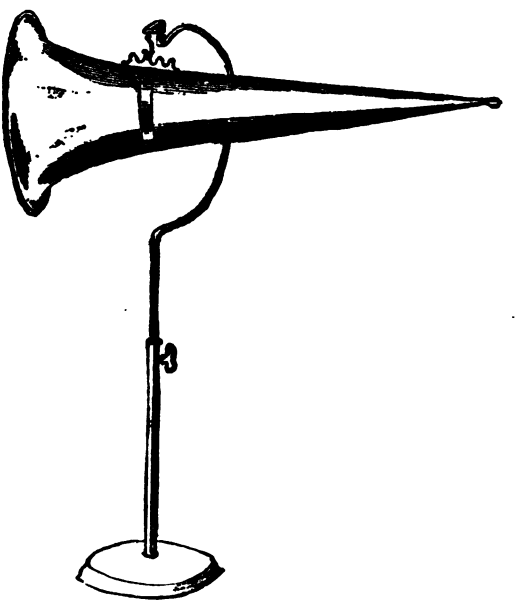


FIG. 27.

we illustrate the ordinary "dome" reproducer; at *d* a "Bettini" with 10 rays; *e* shows a reproducer in ebonite case, with percussion-cap-shaped support for the stylus-bead.

§ 14. The mode in which the reproducer is connected to the horn of the phonograph varies with

the type of instrument. In the cheaper models, intended for the reproduction only of sound, and not fitted with any device for recording, the tube of the reproducer is generally made to slide in or over the tube which forms the small end of the trumpet or horn; and this extremity is then split for about half an inch of its length, to give it a certain amount of elasticity, so as to enable it to adapt itself to any trifling variation in the diameter of the reproducer tube. In machines of a better class, such as those furnished with governor-screw and guide-bar (see Fig. 15, § 10), the trumpet or horn is not of necessity connected directly to the reproducer, nor even to the horn-carrier, H; but in the case of large and comparatively heavy trumpets, which require to be slung on a supporting stand (see Fig. 27), the horn is connected to the horn-carrier by an "adapter" of india-rubber tube. It is evident that in this case we must have some means of controlling or varying the pressure of the stylus of the reproducer on the record, so as to enable it to follow correctly every indentation in the "track." To compass this end in the better machines the reproducers are made of more elaborate pattern, as shown at Fig. 28, in which it will be seen that there is a pivoted lever adjustment, with counterbalancing weight, to enable the stylus to rest upon the record with just that amount of pressure needed to bring out the best effects. In some forms of balanced reproducers—*e.g.*, the "Edison Gem," the cell itself does not rise and fall at all, but only the weight and lever connected to the stylus and its diaphragm, or "membrane," as it is sometimes called. The possessor of a good phonograph naturally desires to be able to make *his own records*. The reader of the previous pages

will probably imagine that this desire is easy enough of gratification. He would think to himself all that is to be done is to place the recorder on the end of the horn, put a blank on the mandrel, wind or otherwise start the motor into action, lower the recorder stylus until it engages in the surface of the blank, and then sing, talk, or play near the mouth of the horn. And theoretically he would be correct. But in attempting to put this mode of procedure into practice, he would find things would not run quite so smoothly as they appear on paper. In the first place, it is useless to attempt to "reproduce" or make a record with a phonograph unless it be provided

FIG. 28.

with a governor-screw and guide-bar (see Fig. 15, § 10), that will ensure the recorder cutting its track as a continuous spiral line round the surface of the blank, each convolution being $\frac{1}{100}$ in. from its neighbour. All the higher-priced instruments, such as the Edison, Edison-Bell, the Columbia, etc., are fitted with this arrangement. The New Century Phonograph Company, in their cheapest form of recording instrument, have introduced a very simple but efficient form of guide, which consists, not of a screw, but simply a rack-bar, driven along at the right speed by a cog-wheel engaging in the rack. As this is actuated by the same clockwork that drives

the mandrel, and is geared to move forward $\frac{1}{100}$ in. at each revolution, it serves its purpose very well. Besides this, great care has to be taken that the cutting edge of the recording stylus is set at the correct angle, so as to *cut* and not to scrape or to dig in the substance of the blank. Also precaution must be taken to ensure correct pressure of the stylus on the blank. If too heavy it whistles; if too light it does not cut deep enough, etc., etc. To ensure good results the operator must observe the following precautions:—

§ 15. In order that the record when made should not give disagreeable harsh and tinny tones, it is advisable that the horn or trumpet which collects the sounds should be of *papier mâché*, and not of *metal*, since this last is apt to vibrate itself and set up "harmonics" or "overtones" of its own. Instead of being of the graceful bell-shape employed for reproducing, the recording-horn is preferably made truly conical. The best length of horn for this purpose lies between 14 ins. and 24 ins.; the mouth should be 10 ins. in diameter. The enthusiastic amateur can easily make a suitable horn by striking out seven quarter circles (quadrants) of 30-in. radius, from stout brown paper, and then cutting them out with the scissors. We show the form and dimensions of one of these quadrants at Fig. 29. It will be seen that if one of these quadrants be rolled up in the shape of a sugar-loaf it will form a cone, with an opening 10 ins. in diameter at its base, diminishing to a point at its apex. The extra 1-in. strip left on one side is to allow that edge to lap over the opposite edge to which it is to be stuck down with a little freshly-made *rather thick* flour-paste (see Fig. 30). When this

cone has been joined up it must be allowed to dry thoroughly. Then, one by one, the other quadrants (which must *not* have the extra 1-in. lapping piece) are brushed over with good stiff paste, and pasted over the first cone, care being taken, firstly, to break joint; that is to say, to let the line of joining the edges come at the opposite diameter of the cone to that at which the first lap occurred; and, secondly, that the second sheath should be adhering *all over* to the first. This should be allowed to dry thoroughly *without losing shape.* This can be effected by support-

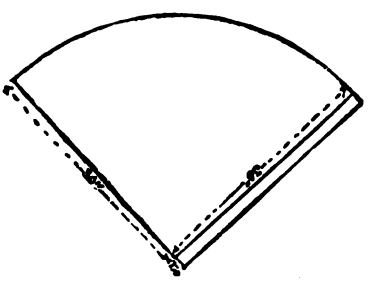


FIG. 29.

FIG. 30.

ing it inside on any cylindrical body of 4 ins. or 5 ins. in diameter, on which it can stand like an extinguisher on a candle. In like manner, the other five quadrants are pasted over the original pair, using the same precautions as to bringing the joined edges at different points of the circumference. When all is thoroughly dry and hard, the operator selects a piece of thin brass triblet tubing that fits precisely the horn-carrier of his phonograph. Of this he will cut off and smooth up a length of about 2 ins. Allowing the apex of the cone he has just made to enter into the tube as far as

it will go, he will make a pencilled line round the apex at this point; then with a sharp penknife cut the apex off round this line. If the tube will not enter without, he will coax the hole so as to make it admit the tube, by rubbing round the inside edge with a smooth pencil or similar hard cylindrical body. The brass tube is now to be smeared on the outside, for about half its length, with a little Prout's elastic glue. This extremity must be made as hot as the hand can bear, and then pushed in the hole in the apex of the cone, until only one inch protrudes, care of course being taken not to ruck up the inside of the cone, but to leave the bore of the tube quite open. With a piece of fine twine dipped in good glue, or, better, with a piece of shoemaker's "waxed thread," the extremity of the cone is tightly bound round, in several convolutions, so as to fix it firmly to this brass tube or nozzle. Finally, to ensure rigidity and firm connection between this tube, or nozzle, and the cone which forms the trumpet or horn, a piece of tape, about 1 in. wide and of sufficient length to make five or six turns round the nozzle, should be brushed over with a little good hot glue, and bound tightly round so as to grip both the end of the cone and the middle portion of the tube. By manipulating this last binding with the fingers, while the glue is still hot, it will be easy to make it fit tightly to both and to the twine-binding underneath. As this trumpet or horn will be rather heavy, it may be desirable to sling it on a stand as shown at Fig. 27. For this purpose it will be well to find its centre of gravity when supported horizontally. At this point, on the outside, will be glued a band of rather wide tape, to the centre of *which is stitch*ed a hook. This band will naturally

encircle the entire circumference of the horn at this point. The nature of the composition of the "blank" next demands our attention. When "recording" we should work in a rather warm room, unless the blank is of very soft material, since with any temperature below 70° Fah. the ordinary blanks will give but a very shallow and poor record owing to their comparative hardness. If the blank is in proper condition, the stylus of the recorder should cut it and deliver the cuttings in the form of minute curly shavings, as fine as a hair, and not as a powder—this would point to the blank being too hard. The angle made by the stylus with the surface of the blank is all important, and this must be tested by noticing whether it is scratching only or whether it is really cutting. With a steel stylus the edge can be readily ground to any angle, but with a sapphire tool it is only by altering the position of the gem in its setting that the correct angle can be got if it be defective, and in this case recourse had better be had to the original maker. In no case should there be any screeching, whistling, or chattering noise, while the blank is rotating under the stylus. Any such sounds will be certain to make themselves painfully audible in the finished record. For this same reason the driving mechanism of the phonograph should run absolutely noiselessly. If the recorder-box be too light it must be weighted ; if too heavy it must be raised, or the counterpoise (if any) be thrown further back, as explained in § 14, latter half. The mandrel of the phonograph should be arranged to run at about 160 revolutions per minute. Having tested the recorder for correct height, the blank is placed on the mandrel and the recorder lowered on it. The machine is now started, and

attention is paid to the nature of the track produced. If all appears satisfactory, the singer stands in front of the horn with his mouth facing it at a distance of about 2 ins. or 3 ins. only from the "bell," into which he will sing. The singing must be loud, with *distinct articulation*. In taking high notes the voice must be softened down a little. This is particularly the case with ladies' voices, otherwise a harsh screech, technically called "blast," will be the result. The voice must be emitted freely, the mouth being well opened and not with the teeth half closed, as is the usual English style. The fashionable "vibrato" comes out very badly. Singers who adopt that style, and especially male voices, produce records which on reproduction remind one forcibly of the baaing of sheep. In records of speech the speaker's mouth must be close to the trumpet, and he must speak loudly and very distinctly, just as if he were addressing an audience at a distance of about 50 ft. from him. Piano records require the horn to be placed as near to the *back* of the piano as is possible, without touching, the back frame having previously been removed. The player must play with a very firm touch, rather banging than slurring; on no account may either loud or soft pedal be used, the former being specially objectionable, as it translates itself on the records as an indistinguishable jumble of wavy sounds. All expression must therefore be got by *touch*, and not by pedals. The cornet and the clarionette both give excellent records: the former, if played at a distance of about 4 ft. from the horn; the latter, if at a distance of 9 ins. The heavier brass wind instruments may be placed at from 5 ft. to 6 ft. from the mouth of the horn. *Whistling* and the piccolo require a distance of from

9 ins. to 1 ft. between the instrument and the horn's mouth. The banjo is perhaps the instrument that gives the most perfect records. The performer should be seated so that his instrument faces the horn, on a level with it, at a distance of about a foot from it. The zither and the mandoline require the same distance. It must be borne in mind that the most pleasing voices are not always those that give

FIG. 31.

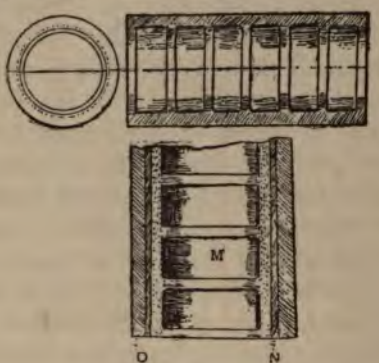
the best results; a rather hard, blatant voice usually furnishes a better record than a soft, sweet one. Male voices generally come out more true to the singer's timbre than ladies', the delicate overtones of these latter being more altered in recording. The work of reproducing should always be performed in a very warm room, the temperature of which should be between 70° and 80° Fahr. to ensure the surface of the blank taking deep indentations. At Fig. 31

we illustrate the arrangement and position of the singer, the piano, and the phonograph controller, in the act of producing at one time five vocal records with pianoforte accompaniment, as adopted by the New Century Phonograph Company at their works in Hatton Garden. The best position for a speaker desirous of recording a speech would be the same as that of the singer in Fig. 31. One precaution must always be taken while the records are being made, and that is to remove the shavings cut up by the stylus as fast as they are produced, otherwise they might adhere to the surface of the track and falsify the tones. On the manufacturing this is effected by blowing a current of air on the surface of the blank while the record is being cut; on the small scale a soft camel-hair brush is held lightly on the surface of the record. No pressure at all must be used, as this would tend to slacken the speed of rotation, which, as we have said before, must be kept pretty high, and must be maintained at one constant speed for each record, otherwise the "pitch" of the record will be flatter at those portions where the blank rotated more slowly; hence the air will appear out of tune.

§ 16. Although the amateur will probably not care to get copies of his own or other records, this work would be incomplete without some notice of the different modes that have been adopted to obtain many *replicas* from a good "master" record. For commercial purposes the power of multiplying records is of the highest importance, since to obtain the services of a good singer or a band of first-class instrumentalists may cost anything from £5 to £100 per "sitting." The "master," and also the actual or *working* records, are shaped as shown in Fig. 32.

They are, as already stated, about $4\frac{1}{2}$ ins. long and $2\frac{3}{8}$ ins. in diameter. The bore is taper $\frac{1}{8}$ in. to the foot, to suit the phonograph mandrel, and a number of recesses are formed in the inside, as shown, leaving bearing surfaces or rings $\frac{3}{16}$ in. wide. The master blanks are moulded from a white wax preparation. The inside is finished, and the outside then turned a few thousandths of an inch taper. The finished blanks must be made as smooth as glass, and have the appearance of polished ivory. They are turned, or "shaved," as it is technically called, on small phonograph mandrels mounted on a work-bench, and belted from shafts at the back of the bench. Provision is made, by means of an air-blast, to blow away all shavings produced during the process of turning up, as these would adhere to the soft wax, and spoil the perfect smoothness of the blank. The cutting-tool, which operates at the back of each machine, is adjusted by means of a screw, with a micrometer dial. The work requires to be rotated at a high speed. Not every blank cylinder that is placed in the phonograph behind the big horn comes out a perfect master: far from it. More or less experimenting is required to find the most suitable recorder—that is, the sensitive diaphragm with its holder and sapphire cutting-point—for the case in hand. And then great attention has to be paid to the proper bringing out of the different musical instruments or different voices. The master records, as they are made, are thoroughly tested, both by musical and by mechanical inspectors, to detect any errors or imperfections in the quality of the music reproduced or in the workmanship of the record. With the master running in the phonograph, the trained ears of the specialists enable them to

detect the most minute imperfections. As a result, many "masters," which to most people would appear to be all that could be desired, are rejected. An examination is then made, under a powerful microscope, to ascertain whether the wax surface of the cylinder is satisfactory in all particulars. Then comes the making of the mould from the master record. The first operation consists in causing an infinitesimally fine coating of gold to be deposited on the outer sur-



FIGS. 32 AND 34.

face of the record, with a view to rendering it a good conductor of electricity. This coating must of necessity be so thin, even, and delicate, as not to alter the relative heights and depths of the indentations existing on the record. To effect this, the apparatus invented by Mr. Edison and shown at Fig. 33 is employed.* This consists in a ground-glass base, F, on which stands a rather tall glass bell, E, which fits air-tight on a chamfer in the said base. On one side

* The description of this apparatus is condensed from an article by *F. A. S.*, in *The American Machinist.*

of the glass bell at S rises a standard, which is curved at the top, so as to stand centrally over it, and this carries a pulley, P, with a cranked arm, that bears at its extremity a magnet, L, the pole of which just clears the outside of the glass bell; so that by driving the pulley the magnet can be caused to revolve

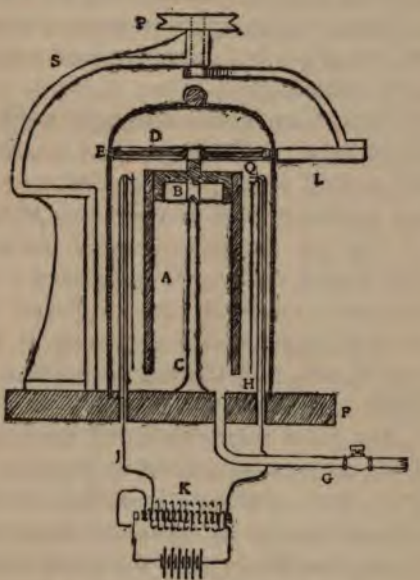


FIG. 33.

rapidly round the glass bell, E. Rising from the centre of the base is the conical-headed pillar, C, which supports on its point a flanged disc, or "head," B, that serves to sustain, as shown, the master record, A. On a prolongation of the central portion of this disc or head is placed a soft-iron armature, D, which, when the magnet, L, is caused to travel round the outside

of the bell, E, by driving the pulley, P, pulls the armature, D, round, causing it to enter into the same rotary motion, of which the disc, B, and the record, A, consequently partake. In the base, at G, is an opening through which fits hermetically a pipe and stopcock connected to an air pump, by means of which a good vacuum can be produced in the bell, E. On the same base, at diametrically opposite points, close to the insides of the glass bell, rise two well-insulated and hermetically-sealed glass tubes, H, inside which pass metal conductors, each terminating in a little projecting metallic hook. From each of these hooks is suspended a gold leaf, Q. The wires, or conductors, which pass up the centres of the tubes, H, and sealed thereto at the top (so as to prevent the entrance of air), are prolonged below, J J, so as to be capable of connection, when required, with a coil and battery, or other source of high-tension electricity, K, which sets up a kind of arc, and thereby volatilizes the gold. To work the apparatus, the record, A, is slid on the head, B. The air is then exhausted from the bell, E, by aid of the air pump attached to the pipe, G. When the vacuum thus produced is sufficiently high, the stopcock is closed, and by means of the pulley, P, the magnet is set revolving round the glass bell, E. The current is now turned on, and allowed to work until a sufficient coating of vapourised gold has been deposited on the surface of the "master" to render it conducting. This mode of imparting conductivity to the master record is due to Mr. Edison, and is the process adopted for the production of the "gold-moulded" records. Many operators, however, are satisfied with a much simpler method, which consists essentially in brushing over the surface of the record

with graphite dust (specially fine), or with very fine bronze or aluminium dust, a very fine, soft camel-hair brush being used for this purpose. This requires excessive care not to injure, deface, or clog-up the delicate indentations on the surface of the record. Whichever method be adopted, the conductive record is now slung at its two extremities by copper-wire loops, and immersed in an ordinary sulphate of copper bath and electro-coppered, until a copper coating, or "shell," of about $\frac{1}{16}$ in. thick, has been deposited equally all round it. This takes about four days to effect. This copper shell, with the record still within it, is then turned off smooth and straight on the outside, and fitted into a brass tube, which really forms the body of the mould. A section through the mould would now appear somewhat like Fig. 34—M being the master, N the copper shell (between which and the wax surface is the excessively thin coating of gold), and O the brass tube into which is fitted the copper shell. The wax record is now removed from the mould by placing this latter for a few moments in a temperature slightly lower than that of the workroom, which, by causing the wax record to contract, releases it from the metal. The inside of the mould, which carries with it the gold lining, is thoroughly cleaned by washing with benzine. The mould is then ready for use. For holding the waxy composition from which the moulded records are made, a number of long tanks, subdivided into nearly square compartments heated by gas, are provided. In moulding the record the mould is lowered into the hot composition by means of an arrangement shown roughly at Fig. 35. In this, P is the mould, Q a cap placed over the top of the latter, and R a can in which the

mould is placed and maintained in a vertical position. The can is carried in a frame, S, which may be moved up and down on uprights, T T, by means of the wire bail, N. The can is lowered into the tank until the top of the mould is below the surface of the composition, V, but not so low as to allow it to enter in at the top of the cap. The molten composition enters into the can by the hole in the bottom, and rises up into the inside of the mould and solidifies thereon, on

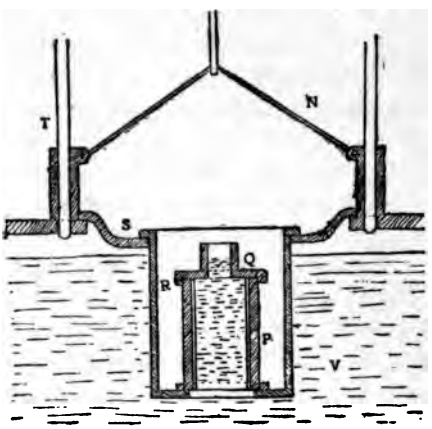


FIG. 35.

coming into contact with the metal; a hollow cylinder of composition is thus formed, the thickness of the wall depending, of course, partly upon the length of time the mould is immersed, and partly on the initial temperature of the molten composition. After remaining therein for a minute or so the can is lifted, the cap taken off, and the mould removed. The *composition* adhering to the bottom of the latter

is removed by a knife, and the mould is then slipped into a special chuck in a machine of the monitor type. Inside-shaving tools, held in the turret of this machine, are then run into the new record to finish the bore. These tools are made of steel tubing cut away to the centre for a length sufficient to reach through the cylinder, and ground to a sharp edge. The tools are somewhat smaller than the rough hole left in the record by casting, and after being run in to the right distance are brought over against the wax wall by a lever which serves to move the turret laterally on its carriage. These tools are required to finish the bore: the first roughs out a plain taper bore; the second (which is notched with furrows $\frac{8}{100}$ in. apart at the edge) cuts out the half-dozen grooves around the inside of the cylinder; the third, or finishing tool, brings these narrow bearing-surfaces left to the correct taper. These shaving-tools operate very rapidly, as the work is rotated at a very high speed, the material of course being softer than anything that the average screw-machine operator has ever had anything to do with. When the work is removed from machine it cools, and in a moment contracts sufficiently to admit of the record being extracted from the mould without affecting the indentations. And as fast as the records are finished inside, they are placed on cast-iron shells, or hollow plugs, to prevent their being injured or becoming distorted in further cooling. They are then slipped, one at a time, on a taper arbor held in a machine-spindle, which is continually in rotation, and the ends are here finished. After this operation, each record is carefully inspected to see if it runs true and if it is free from flaws of all kinds. Having passed this inspection, if satisfactory,

the record is wrapped in cotton, slipped into a cylindrical pasteboard box, and is then ready for packing for shipment. The moulding of these records is, without doubt, one of the most delicate, accurate, and interesting operations ever performed in a shop. Let us consider for a moment the shallowness and delicacy of the indentations on the surface of the master record; the gold-plating of the wax surface, indentations and all; the reproduction by electrotype of each and every tiny swell corresponding to its relative hollow in the master; the accurate rendering upon an endless number of moulded records of every indentation that had been traced on the original wax cylinder. The deepest of the impressions in the master are something less than $\frac{1}{1000}$ of an inch in depth; the shallowest are much less than this. The surface of the cylinder presents to the naked eye a wavy appearance, not unlike that of a chattering lathe-job, and yet all circumferential grooves traced in the wax, along with every shallow indentation, no matter how insignificant it may appear, are faithfully reproduced on the surface of the moulded record. With this process a much harder composition can be used—and, consequently, a more durable record made—than was possible under the old method of cutting each cylinder (which necessitated a much softer composition, in order to ensure a good loud record). Besides, there is practically no wear put upon the copper mould, so that the thousandth record cast or "moulded" in it is as clear and sharp, and will reproduce the vibrations originally received by the master record, as well as the first.

§ 17. Another mode of getting a copy from a good *master record is* by means of a kind of "pantograph,"

of which a rough outline is given at Fig. 36—the "master," R, placed on the mandrel, A, of a phonograph having a guide-screw. On the saddle, or split nut, of this is fixed an upright, carrying at its upper portion a double-jointed lever, L, actuated by a spiral spring, to one extremity of which is attached a little sapphire reproducing-bead, B, similar to those used in the reproducers. The other end of the lever bears at its extremity an ordinary recording stylus, S. Just under this is placed another phonograph mandrel, M, also furnished with guide-screw. On this mandrel is

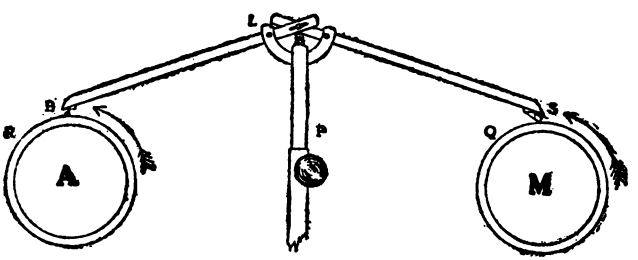


FIG. 36.

placed the blank, Q, on which it is desired to reproduce the indentations of the master record. The upright is then lowered and adjusted by the rack and pinion, P, until both the reproducer-bead, B, and the recording stylus, S, rest correctly and track properly on the master, R, and the blank, Q. When this has been duly adjusted, so that the stylus cuts properly the blank, Q, the two phonographs are started simultaneously, when, by virtue of the action of the levers, every indentation existing in the master will be faithfully reproduced on the blank; and it is even possible, by lengthening slightly the arm of the second half of

the lever, to cut the indentations more deeply than they exist on the master. But the most perfect results are obtained when the two arms are of precisely the same length. Naturally, by this process, the number of copies that can be obtained from one master is limited—partly because, as the master must be cut in soft wax, it gets worn quickly by the travel of the bead in its tracks, and partly because, smooth though this bead be, owing to the pressure it puts upon the wax of the master while working the cutting stylus, it smooths down the higher portions of the tracks thereon.

§ 18. A third mode of obtaining a copy of a favourite record, and one which is well within the grasp of the amateur, consists in placing the record to be copied on the mandrel of one phonograph, and the blank on the mandrel of another. Both phonographs are then set in motion, the first instrument sending its vibrations into the horn of the other. The following precautions must be observed to obtain good results by this method. 1st, the phonographs must both be fitted with papier-maché horns, metal being inadmissible. 2nd, the phonograph on which the blank is placed, and which is fitted with the recorder, *must* have a guide-bar, so as to produce a track, the convolutions of which are $\frac{1}{100}$ of an inch apart. 3rd, that the horn, or trumpet of the reproducing phonograph, should have its bell at least twice the diameter of that of the bell of the one on which the master record is placed. This is to ensure the sound-waves always entering the horn, notwithstanding the opposite motions of the two horns. 4th, the two horns must be placed with their mouths, or bells, *as close as* possible without actually touching at any

part of their travel. 5th, the speed of the two phonographs should be as nearly the same in both instruments, otherwise the copy will come out in a different key. Fig. 37 is an illustration of an Edison Bell "Gem" phonograph, showing how the "balanced" reproducer, mentioned in § 14, is affixed to the horn.

§ 19. Very shortly after the invention of the "tinfoil" phonograph by Edison, in 1878—in which, as we

FIG. 37.

have seen, sounds produced near the instrument impressed indentations vertically into the surface of the cylinder rotating under the stylus—several experimenters sought to improve the speech of the talking machine by changing the direction in which the stylus acted on the said surface. Among the most successful of these was M. Emil Berliner, who in 1887 showed by his "gramophone" that very excellent results could be obtained by placing the stylus in

such a position with reference to the surface on which the sound vibrations were to leave their traces that these vibrations should translate themselves into sinuous lines, parallel to the receiving surface, instead of digging into it vertically, thereby producing valleys and hillocks. It is evident that to obtain this result it is necessary that the stylus should move horizontally from right to left, instead of perpendicularly up and down. Fig. 38 shows the difference between the two kinds of tracings referred to: *a* being a magnified representation of the vertical indentations produced by the ordinary "phonograph" recording stylus; while *b* illustrates the corresponding laterally waving line produced by the Berliner or "gramophone" stylus. We shall not enter very deeply into a detailed description of the driving mechanism by which the disc (which takes the place in the gramophone of the cylindrical record used in the phonograph) is kept rotating; suffice it to say that any of the devices used in the phonograph—as, for instance, a small hand-wheel, an electro-motor, or a spring and gear wheels, with suitable governor (see § 9)—may be employed. In the original form a small wheel driven by a handle communicated its motion by a band, gut, or friction wheel, to a small pulley pivoted horizontally on a central vertical pin. Attached horizontally to the upper surface of this pulley was a circular metal table, faced with cloth. On turning the handle this table entered into rotation, carrying with it the disc or record, which was laid over it, and held firmly on it by a nut screwing over the projecting end of the pivot. So far, the gramophone differs but little from the phonograph, except *that the* "record" takes the form of a flat disc instead

of a hollow cylinder. When the instrument is used for *recording*, a device similar to the guide-bar (§ 10) must be adapted to the rotating mechanism, so as to carry the recording stylus from the circumference in a straight line towards the centre of the record disc, so that the track inscribed on its surface should take the form of one long continuous wavy spiral, the individual turns of which lie $\frac{1}{100}$ of an inch apart. This is not needed when the reproducer, or "sound-box," is being used, as the spiral lines constituting

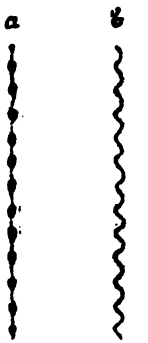


FIG. 38.

the track are sufficiently deep to guide the stylus and ensure its following the track. The chief point of difference lies in the construction of the "box" which holds the stylus, whether for recording or for reproducing. At Fig. 39 we illustrate the form and arrangement of the parts of a "sound-box" of this description of the best modern make, for the facilities of presenting which we are indebted to the courtesy of the manufacturers of the Gramophone talking machine. At A is shown the diaphragm, to the centre of which is attached the stylus carrier a. Near

its lower extremity this carrier (which is hollow for a short distance of its length) is fitted with a transverse pivoting needle, *bb*, which pivot plays freely but with exactitude in suitable bearings in the cover of the box, thus enabling the stylus (the shank of which enters into the hollowed portion of the carrier) to oscillate freely in obedience to the vibrations of the diaphragm when used as a recorder, or to convey the oscillations to the diaphragm when used as a reproducer. The stylus, which takes the form of a short stout needle, *c* fits into the carrier, and is held in

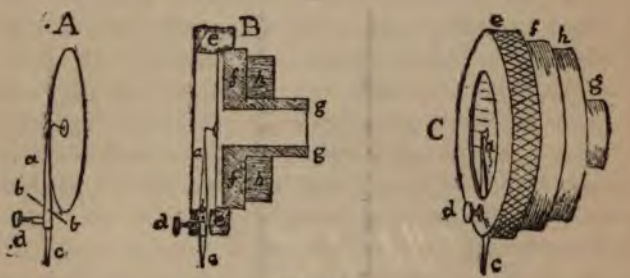


FIG. 39.

place by a small milled-headed screw, *d*. This screw projects beyond the edge of the cover of the box, the shank passing through a hole of sufficient size to allow it to oscillate freely. This enables the operator to remove and replace at will the needle forming the stylus without any difficulty. This is essential, because, as the material used for the records is very hard (ebonite), it rapidly takes the polish off the end of the stylus, which, in order not to injure the records, should be exchanged after each run. In the same figure, at B, we give a sectional view of the sound-*box, showing* how the stylus carrier, *a*, is fastened at

one extremity to the face of the diaphragm and pivoted to the cover *e* at *b*, indicated by a dot; the milled screw, *d*, serving to clamp the stylus, *e*, in its position in the tube of the carrier *b*; *e* is the screw-cap or cover of the box, which fits on *f*, that forms the bottom of the box, and which is prolonged to *g*, in the form of a tube, that communicates either directly or indirectly with the horn, or trumpet; *h* is a stout indiarubber ring that makes an air-tight connection with the said horn; lastly, at C of this same Fig. 39, we give a perspective view of the complete sound-box. In these three views, as similar parts are lettered homologously, the intelligent reader will readily perceive how they are put together, and how, by pivoting the carrier or lever, *c*, it is possible to give a lateral swaying motion to the stylus, instead of an up-and-down movement. The sound-box of the gramophone weighs much more than the corresponding reproducer or recorder of the phonograph—usually about 6 ozs. This is not found disadvantageous—partly because the surface of the records employed is so much harder than those of the phonograph, and because the tracks, being wavy lines of equal depth, do not get worn much; and partly because the weight of the trumpet or horn is never borne by the sound-box. This latter, for the convenience of changing the records, etc., is supported by a hollow tubular arm, delicately pivoted on a side bracket, so that it can be readily turned aside, and follows with ease the spiral track of the record. Over this tubular arm, swivelling in the same bracket, is adjusted the horn or trumpet, which can therefore be turned in any direction in an horizontal plane, without interfering with the play or position of the

sound-box. The sound-box itself is attached to the tubular arm by a hollow U-shaped tube, fitting accurately into one side of the arm, which allows it to be turned back when it is desired to renew the stylus needle without removing the sound-box altogether. We illustrate in our Fig. 40 the complete arrangement. The dotted lines show the position occupied

FIG. 40.

by the sound-box when swung back on the tubular arm—the mode in which this latter is delicately poised between the jaws of the bracket. The mode in which the horn is made freely movable, by allowing its extremity to ride in a circular channel, is also indicated. We may now pass to consider how the *disc records* for the gramophone are usually made.

The essential parts of the recording instrument are the turn-table, the worm-screw which guides the tubular arm (or "carriage") holding the recording diaphragm, and the recording diaphragm itself. The action of this mechanism is to guide the recording diaphragm in such a manner—from circumference towards the centre, while recording the sound—as to cause it to trace a continuous spiral line. The method of making the record is to place upon the turn-table a highly-polished disc of zinc previously coated with a film of fat, exceedingly sensitive to the touch of a lightly-bearing stylus, but dense enough to resist the action of the acid in an etching bath. When the machine is set in motion, and the singer or player is executing music, etc., before the horn, the stylus transfers the wave vibrations from the diaphragm to the zinc surface by cutting a wavy track in the fat and baring the zinc below. During this operation the surface of the disc is kept flooded with alcohol from a reservoir fitted with a tap. The object of this is to soften the fatty film, and to prevent particles of the film or of dust from collecting round the point of the stylus, which would otherwise falsify and destroy the truth of the sound wave. The record being thus made, the zinc disc is taken off the turn-table, and the alcohol rinsed away. The disc is then placed in a bath of chromic acid, which respects the portions protected by the fatty film, but attacks and etches the zinc at those places where the stylus has bared the zinc by removing the fat. The length of time consumed in this etching process depends entirely upon the amplitude of the wave vibrations. Recorded waves of small amplitude require but short etching; those of large amplitude long etching.

When taken from the etching bath, the disc is well washed and carefully cleaned and dried, when it is ready for the first trial. As this first trial with the reproducing sound-box has for its purpose the cleaning out of the etched spiral groove the sound is at first somewhat harsh and grating; but on running it two or three times any dirt or roughness is removed, and the record becomes smooth and quieter. The zinc record is now ready for the duplicating process. A copper matrix is first made from it by electrotyping as already described for phonograph moulds—only in this case, as the zinc is a good conductor of electricity, no previous gilding is required. The copper bath for this purpose must be of the alkaline type——viz., ammonio sulphate of copper dissolved in potassium cyanide. From the copper matrix thus produced any number of duplicates can be moulded out of ebonite by hot pressure, in the manner usually adopted in making pressed ebonite or vulcanite goods. These ebonite records are superior to the zinc original in several ways. They will bear rough handling and an indefinite number of reproductions, whereas the zinc burnishes and soon wears away. They speak louder and more smoothly than the zinc. The ebonite records will stand over 1,000 reproductions; the zinc from 50 to 300 only, according to their delicacy. A first-class matrix will admit of 1,000 duplicates being pressed out from it. In concluding, we must acknowledge our indebtedness to Mr. Limb, of the Edisonia and Edison Bell Company; and to Messrs. Waterfield, Clifford, and Co., of the New Century Company, by whom we have been favoured with much interesting information.

INDEX.

PAGE.

ACCUMULATOR for motor 35
Adapter 52
Air, velocity of sound in ... 9
Aluminium 48, 59
Amplitude 11, 15, 19
Angle for nozzle 52
Apparatus for casting records 44, 74
duplicating ... 68, 77
gilding 70
Armature for motor ... 31
Articulation 66

BALANCED reproducer . 60
Ball-bearings for motor 31
Banjo records 67
Barrel for spring 35
Battery for electro-motor, 34, 35
Bead or stylus 56
Beads, glass for 55
Bearings 22
Beeswax fastening 54
Berliner's "Gramophone"... 79
Best speed 65
Bettini reproducer 58
Bidwell's phonograph 21, 25
Blanks ... 44, 45, 65, 69, 77
composition for ... 45
concert type 44
making 44
moulds for 45
ordinary 44
wax for 45

PAGE.

Box for recorder 49
reproducer 49
Brasses for electro-motor ... 32
Breaking glasses by voice... 11
Brushes for electro-motor ... 33

CARRIER, horn 60
Casting records 44, 74
Cause of sound 9
Celluloid 59
Cement (shellac) 57
Clarionette recording ... 66
Clockwork for phonographs 35
Cog-gearing 36
Cog-wheel 61
Collar, movable 43
Collodion 18
Comparison of phonograph and Gramophone tracings 81
Composition for blanks ... 45
Commutator 33
Columbia phonograph ... 61
Connections to electro-motor 33, 34
horn 59
Concert type blanks ... 44
Continuous spiral line ... 81
Copper matrix from zinc record 86
Coppering, electro- ... 73
Copying records 68
Cornet recording 66
Current for motor 35
Cylinder 22

PAGE.

DEVICE for stopping ... 40
Diaphragm, or membrane 13, 18, 24, 48, 53, 58, 60, 82
glass for 48
Dimensions 23
Disc records 85
Distance for recording ... 67
Dome 56, 59
Dressing field-magnets ... 33
Driving mechanism for Gramophone 80
phonograph 31
Duplicating apparatus, 68, 77, 86

EAR, limits of range of hearing 9
Ebonite records 86
box 49
rocker 33
Edison Bell phonograph ... 61
Gem 60, 79
phonograph 61
Edison's experiments ... 19
first phonograph ... 20
gilding process ... 70
phono-motor 31
Electric current 35
Electro-coppering 73
magnet 18
motor 31
battery for 34, 35
brasses for ... 32
brushes for ... 33
connections to 33, 34
wiring 33
Etching zinc disc 85
Experiments by Edison ... 19
showing wave motion, 10, 15

FAN for regulating speed, 38
Ferrotype ... 19, 25, 53

PAGE.

Field-magnets for motor ... 31
Flat disc records 80

GEARING, cog 36
Gem phonograph 60, 79
Gilding master records ... 70
Gillett's motor 35
Gold-moulded records ... 73
Glass beads 55, 56
for diaphragms ... 48
Globe polish box 57
Governor 37
screw 61
Gramophone 79
needle 82
sound-box 81
tracings 81
Grand or concert type record 44
Graphophone 20
Guide-bar 42, 61, 81
Gummed paper 54

HALF-NUT 42
Harmonics 62
Hearing, range of 9
High notes 15
Horn or trumpet— 43, 52, 60, 62, 83
carrier 60, 83
connections to 59
stand for 64
to make 62

IMPORTANCE of touch. 66
Indiarubber rings ... 53
Instructions for making motor 31
phonograph 21
reproducer 51

PAGE.

KRATZENSTEIN'S machine 16
Kempelen's machine ... 16

LAMINATIONS for motor 31
Lathe for records 75
Leon Scott's phonautograph 13
Loudness and amplitude ... 19
dependent on wave size 15
Low notes 15
sounds 9

MAGNET, electro- ... 18
Making blanks ... 44
glass beads ... 55, 56
recorder 49
records 60, 81
reproducer ... 51, 57
tracings 14
Mandrel 41, 44
speed 65
Master records ... 68, 69
gilding 70
Materials for diaphragms, 53, 58
for blanks 44
Matrix from zinc record ... 86
Membrane, or diaphragm—
13, 18, 53, 58, 60, 82
Mica 48
Motor, accumulator for ... 35
battery for ... 34, 35
brasses for 32
brushes for 33
electro- 31
Gillett's 35
spring for 35
wiring for 33
Moulded records, gold ... 73
Mould for blanks 45

PAGE.

Movable collar 43
Musical sound produced by glass 11

NEEDLE, Gramophone ... 82
necessity for replacing 82
New Century phonograph ... 61
Notes, high 15
low 15
Nozzle 43
angle for 52
soldering 52

ORDINARY blanks ... 44
Original form of Gramophone 80
Oscillations of the Gramophone diaphragm ... 82
Overtones objectionable 62, 67

PACKING records ... 76
Pantographic duplicator 77
Paper fastening 54
Papier-mâché horn ... 62
Pedal objectionable ... 66
Percussion-cap dome ... 59
Piano recording 66
Piccolo recording 66
Pitch or tone ... 11, 68
Pivoting needle 82
Phonautograph 13
Phonograph, Bidwell's 21, 25
clockwork for 35
Columbia 61
Edison 61
Edison Bell 61
Edison's first 20
Gem 60, 79
New Century 61
tracings 81

2702901

PAGE.

Phonomotor 31
Process of gilding records... 70
Punching hole 52

RACK bar 61
Range of hearing ... 9
Rate of vibrations 9
Recipes for composition— 45, 46, 47
Recorder ... 30, 41, 48, 49, 81
Bidwell's 25
box for 49, 82
Recording 18, 66, 81
banjo 67
clarionette 66
cornet 66
distance for 67
piano 66
piccolo 66
speeches ... 66, 68
speed for 65
temperature for ... 67
vocal 66
whistling 66
Records 30, 85
casting 44, 74
copying 68, 86
ebonite disc 86
gold moulded 73
lathe for 75
making 60, 66, 68
master 68, 69
packing 76
sizes of 44
tin-foil for ... 21, 28
zinc 86
Reed 17
Regulation of speed ... 37
Reis' machine 18
Rendering vibrations visible 10

PAGE.

Reproducers— 27, 41, 48, 50, 51, 57, 58, 82
balanced ... 60, 79
Bettini's 58
Bidwell's 27
Gramophone's 82
Replicas 68, 86
Rings, indiarubber 53
Rocker, ebonite 33

SAPPHIRE for recorder 49, 55
for reproducer 55
Savart's wheel 12
Screw-cutting lathe ... 44
governor 61
Seccotine 53
Shavings 68
Shellac cement 57
Shrill sounds 9
Singing 66
Sizes of records 44
Slow waves 9
Soldering nozzle 52
Sound-box 51, 83
Sound, cause of 9
experimental illustration 10
tracings 14, 81
Sounds, low 9
shrill 9
Speech, recording ... 66, 68
Speed 37, 65, 79
for recording 65
Spider support ... 56, 58
Spindle 22
Spinning brass box... ... 51
Spiral line, continuous ... 82
Spring, barrel for 35
Spring for motor 35
Stand for horn 64

PAGE.
Standards 22
Steel for diaphragms ... 48
for stylus ... 48, 50, 82
Stopping device 40
Stylus ... 41, 48, 55, 82
Suggett's recipe for blanks... 46
Support or dome 56

TELEPHONE 19
Temperature for recording 67
Tin-foil for records... 21, 28
Tone or pitch ... 11, 68
Touch important 66
Tracings by sound ... 14, 81
comparison of 81
Track... ... 60, 61, 66, 81
Transmitter 18
Triblet tube 52
Trumpet, or horn— 43, 52, 60, 62, 83
to make a 62
Tubular arm 83
Turntable 85

VEGETABLE wax ... 47
Vibration rate decides pitch 15

PAGE.
Vibrato, bad... 66
Vibrations 9, 13, 14
counting 12
rendered visible ... 10
Vocal, recording 66
Vowel sounds 16

WAVE motion 9
Wave, size determines loudness 15
Wax for blanks 45
Weight of sound-box ... 83
Weighting the reproducer... 49
Wheel, cog 61
Savart's... 12
Whistling, recording ... 66
Willis' experiments... ... 17
Wine-glass, experiments on 10
Wiring for electro-motor ... 33
Working Bidwell's phonograph 29
Worm-screw... 85

ZINC disc etching ... 85
matrix from... ... 86

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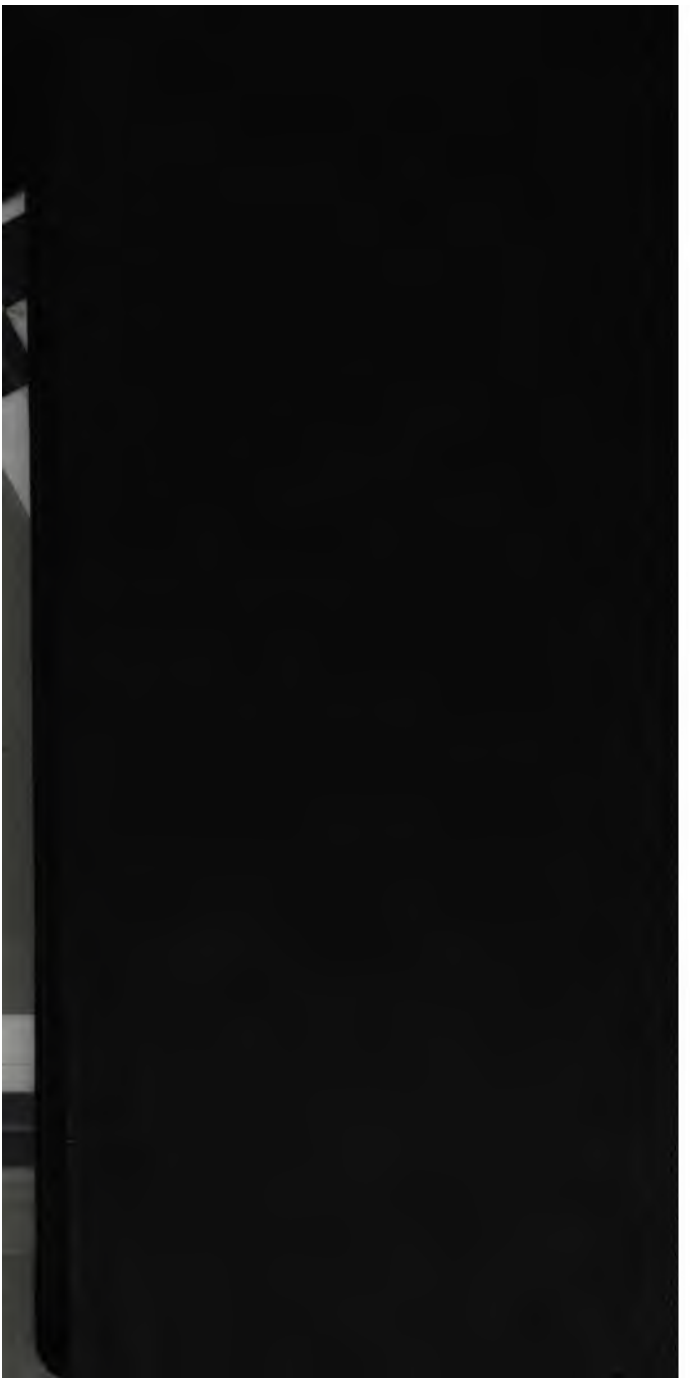
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